waste site. If potentially hazardous constituents of coal combustion waste do migrate and produce environmental contamination, it could affect species and natural communities that are particularly vulnerable, thereby lessening ecosystem diversity.

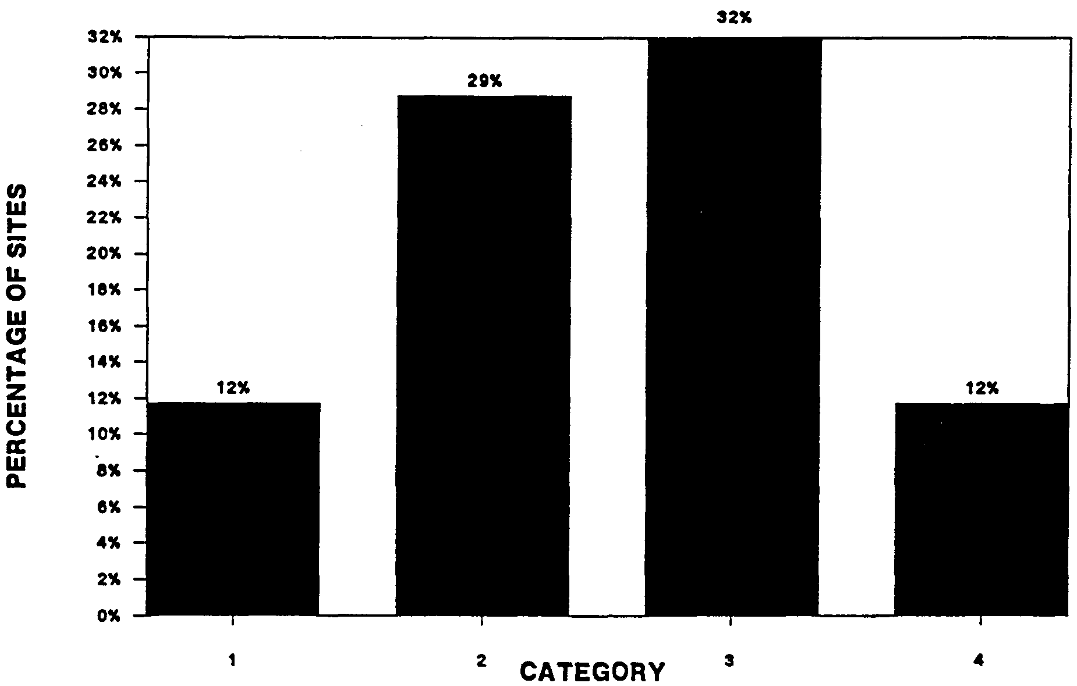
EPA provided Heritage Program staff with latitudes and longitudes for the sampled sites in states that had such programs. Using these coordinates, the Heritage Program staff performed a search of their data bases for rare or endangered species within a five-kilometer radius from the site.

The sample sites were grouped into four categories based on the results obtained from the Heritage Program. Category 1 includes sites having Federally designated threatened or endangered species within the five-kilometer radius. Category 2 includes sites that have no Federally designated threatened or endangered species within the five-kilometer distance, but which do contain species or natural communities designated by state Heritage Offices as critically endangered in that state. Category 3 contains sites for which there are species or natural communities of concern in the area. For sites in Category 4, there is no record of the existence of species of concern in the five-kilometer area.

Information was available on 85 of the 100 coal combustion waste sites in the sample. Exhibit 5-27 presents the breakdown of sites according to the categories described above. Twelve percent of the sites fall into Category 1, 29 percent in Category 2; 32 percent in Category 3; and 12 percent in Category 4 (no information was available for 15 percent).

EXHIBIT 5-27

ECOLOGICAL STATUS OF WASTE SITES



Category 1 : Federally designated plants or animals within a five km. radius
Category 2: Species of priority state concern within five km. radius
Category 3: species of concern to state environmental offices
Category 4: no data on ecosystem surrounding the site

SOURCE: ICF Inc., based on State Heritage Data

Given the high percentage of sites that have rare plant and animal communities within a five-kilometer radius supplies, and the proximity discussed earlier of waste disposal sites to surface-water bodies (which provide animals with drinking water), there could be a high potential for species exposure to coal combustion constituents.

5.4.4 Multivariate Analysis

The previous sections of this exposure analysis presented independent analyses of the population, environmental, and ecological characteristics of coal combustion waste sites. This section examines a number of these factors simultaneously in order to determine interactions that affect the overall potential for exposure from coal combustion waste sites.

As mentioned previously, only 34 percent of coal combustion waste sites (based on a random sample of 100 sites) have public drinking water systems in the downgradient plume within 5 kilometers of the waste site. Some of these public drinking water systems may use ground water that is currently treated before it is used as drinking water, indicating that human populations are unlikely to be directly exposed to any water that may be contaminated from coal combustion waste constituents. As discussed earlier, one reason for treating the water is ground-water hardness. Ground water that has a hardness greater than 240 ppm $CaCO_3$ is likely to be treated if it is used as a drinking water source. Of the 34 percent of the sites in the sample that have public water systems in the downgradient plume within 5 kilometers of the waste site, just under one-half of these sites have ground water with a hardness over 240 ppm $CaCO_3$. These results show that the potential for human exposure through drinking water is likely to be less than the proximity to public drinking water systems (FRDS data) indicates. Of all the sites sampled, only 18 percent have public drinking water systems within 5 kilometers and ground water under 240 ppm $CaCO_3$.[34]

The potential for human exposure through drinking water can be further evaluated by comparing the FRDS and ground-water quality characteristics with the hydrogeologic factors of net recharge and depth to ground water. Sites with a net recharge greater than 7 inches and a depth to ground water of fifteen feet or less are more likely to develop ground-water contamination due to waste leaching since water has a greater likelihood of contacting the coal combustion wastes. Of the 18 percent of the sites that have public water supplies and ground-water hardness below 240 ppm $CaCO_3$, two-thirds have a net recharge greater than 7 inches as well as a depth to ground water of 15 feet or less. Therefore, only 12 percent of the sites in the sample (18 percent x 2/3) have ground water that is likely to be used without treatment and hydrogeologic characteristics that indicate high potential for leachate migration.

This multivariate analysis of the factors affecting exposure at coal combustion waste sites illustrates the limited potential for human health risk through drinking water. Only 34 percent of the sites have public water systems within five kilometers and many of these public water systems are likely to treat the ground water due to hardness.

5.5 SUMMARY

This chapter has reviewed available information on the potential for coal-fired combustion wastes from electric utility power plants to affect human health and the environment. First, data on the potential corrosivity and EP toxicity of utility wastes was reviewed. After determining that coal combustion leachate sometimes contains hazardous constituents at levels above drinking water standards, the potential for this leachate to migrate from waste disposal sites was examined. Results of ground-water monitoring in several studies were interpreted and a number of compilations of "documented" damage cases were evaluated. After describing instances in which trace elements in coal combustion leachate have migrated from waste disposal sites, the potential effect of these migrations was examined. A sample of 100 utility waste disposal sites was selected, and these sites were evaluated in terms of population, environmental, and ecological characteristics to assess the potential for leachate migration and exposure of human and ecological populations.

Based on these data and analyses, several observations relating to potential dangers to human health and the environment can be made:

- If the current exemption from Subtitle C regulation were lifted for coal combustion wastes and these wastes were required to be tested for corrosivity or EP toxicity, most current waste volumes and waste streams would not be subject to hazardous waste regulation. The only waste stream which has had corrosive results is boiler cleaning waste. (Since coal ash is not aqueous, it cannot be corrosive.) For the other waste streams, available data indicate that while some of these waste streams could have high or low pH levels, they are not likely to fall under the RCRA definition of corrosive waste.

Similarly, while a few high-volume waste samples did exceed the EP toxicity limits for cadmium, chromium, and arsenic, this was limited to a few waste streams and represented only a small fraction of the samples for these waste streams (the chromium and arsenic exceedances were from only one fly ash sample). Available data on low-volume wastes showed that the only waste stream with significant RCRA exceedances was boiler cleaning waste, which had exceedances for chromium and lead. Wastewater brines were shown to exceed the RCRA standard for selenium in one sample. Results of EP tests on co-disposed wastes indicate that boiler cleaning wastes may not possess hazardous characteristics when co-disposed with ash. Results for all other waste streams and all other constituents were below EP toxicity limits.

- Results available from ground-water monitoring studies and documented cases of ground-water or surface-water contamination show some migration of PDWS constituents from utility waste disposal sites. In the most comprehensive and systematic of these studies, the Arthur D. Little survey of six utility sites, evidence of constituent migration downstream from the waste sites was conclusive only for cadmium. The Envirosphere ground-water study showed that only 3.7 percent of the samples showed downgradient concentrations of PDWS constituents that were higher than the concentrations of upgradient constituents (indicating that some contaminants are migrating from the site). This tends to support the results of the waste extraction tests. For the one utility disposal site on the National Priorities List, a site currently inactive since it was closed in 1974, the major ground-water contaminants were vanadium and selenium. However, this site differs from some other sites for which ground-water quality data are available in that wastes are from both coal and petroleum coke combustion.

- Although coal combustion waste leachate has the potential to migrate from the disposal area, the actual potential for exposure of human and ecological populations is likely to be limited. Because utility plants need a source of water to operate, most of the disposal sites are located quite close to surface water. Fifty eight percent of the 100 sample sites were within 500 meters of surface water. It is not common for drinking water wells to be located between the disposal site and the nearest downgradient surface water body. The effect of this proximity to surface water is that only 34 percent of the sampled sites had drinking water intakes within five kilometers. Furthermore, the flow of the surface water will tend to dilute the concentrations of trace metals to levels that satisfy drinking water standards.

- Simultaneously examining the environmental and population characteristics of coal combustion waste sites shows even less potential for exposure to human populations. 12 percent of the sites in the sample have public water systems within five kilometers of the site where the ground water may not be treated (i.e., ground-water hardness below 240 ppm $CaCO_3$) and hydrogeologic characteristics that indicate high potential for leachate migration.

CHAPTER 5

NOTES

1 See 40 CFR 261.21.

2 See 40 CFR 261.22. In using pH to determine corrosivity, EPA explained that "wastes exhibiting low or high pH can cause harm to human tissue, promote the migration of toxic contaminants from other wastes, and harm aquatic life."

3 These methods are set forth in 40 CFR 260.21 and 260.22.

4 See 40 CFR 261.23.

5 See 40 CFR 261.24.

6 See 40 CFR Part 261, Appendix II. These procedures for testing and the limits allowed for determining whether a waste is hazardous or not are currently under review.

7 A waste would be considered hazardous if it has been shown to have an oral LD 50 toxicity to rats of less than 50 mg/kg, an inhalation LC toxicity to rats of less than 2 mg/l, or a dermal LD 50 toxicity to rabbits of less than 2000 mg/kg.

8 See 40 CFR 261.11.

9 See CFR 40 Section 261.24. RCRA also establishes EP toxicity limits for six pesticides.

10 See CFR 40 Section 261, Appendix II.

11 Federal Register, Volume 51, No. 114, Friday, June 13, 1986, p. 21648.

12 Since the completion of the ASTM B tests discussed in this section, ASTM has dropped this extraction test (EPRI 1983).

13 Tetra Tech, Inc., Physical-Chemical Characteristics of Utility Solid Wastes, prepared for Electric Power Research Institute, EA-3236, September 1983.

14 Jackson, L. and Moore, F., Analytical Aspects of the Fossil Energy Waste Sampling and Characterization Project, prepared for the U.S. Department of Energy, Office of Fossil Energy, DOE/LC/00022-1599 (DE84009266), March 1984.

15 Arthur D. Little, Inc., Full-Scale Field Evaluation of Waste Disposal from Coal-fired Electric Generation Plants, prepared for the Air and Energy Engineering Research Laboratory of the U.S. Environmental Protection Agency for the Office of Solid Waste, EPA-600-7-85-028, June 1985.

16 Mason, B.J., and Carlile, D.W., draft report of Round Robin Evaluation for Selected Elements and Anionic Species from TCLP and EP Extractions, prepared by Battelle Pacific Northwest Laboratories, for the Electric Power Research Institute, EPRI EA-4740, April 25, 1986.

17 Battelle's test varied from standard TCLP procedure by allowing 14 days, rather than the normal 7, for the completion of the test.

18 Electric Power Research Institute, "Mobilization and Attenuation of Trace Elements in an Artificially Weathered Fly Ash," prepared by the University of Alberta, Edmonton, Canada, EPRI EA-4747, August 1986.

19 Battelle Pacific Northwest Laboratories, Chemical Characterization of Fossil Fuel Combustion Wastes, prepared for the Electric Power Research Institute, September 1987.

20 Radian Corporation, Characterization of Utility Low-Volume Wastes, prepared for the Electric Power Research Institute, May 1985.

21 Radian Corporation, Manual For Management of Low-Volume Wastes From Fossil-Fuel-Fired Power Plants, prepared for the Electric Power Research Institute, July 1987.

22 Arthur D. Little, Inc., Full-Scale Field Evaluation of Waste Disposal from Coal-fired Electric Generation Plants, prepared by the Air and Energy Engineering Research Laboratory of the U.S. Environmental Protection Agency, for the Office of Solid Waste, EPA-600-7-85-028, June 1985.

23 Franklin Associates, Ltd., Survey of Ground-water Contamination Cases at Coal Combustion Waste Disposal Sites, prepared for U.S. Environmental Protection Agency, March 1984.

24 Envirosphere Company, "Report on the Ground Water Data Base Assembled by the Utility Solid Waste Activities Group," in Utility Solid Waste Activities Group (USWAG), Report and Technical Studies on the Disposal and Utilization of Fossil·Fuel By-Products, October 26, 1982, Appendix C.

25 It is not necessarily true that measurements taken from upgradient and downgradient wells at approximately the same time yield comparable measurements. In fact, due to migration time, there will be a lag between the time of comparable upgradient and downgradient measurements.

26 Envirosphere Company, Op. cit., p. 38. These percentage numbers do not correspond precisely to the data in Exhibit 5-11 because Envirosphere normalized the data it received from the utilities so that each facility would be weighted evenly (i.e.,, a facility with many more measurements would not be weighted excessively). Envirosphere reports that 1.7 percent of the normalized data had upgradient measurements lower than the PDWS and the downgradient higher than the PDWS; 5 percent of the data indicated that both values exceeded the standard.

27 Envirosphere Company, Environmental Effects of Utility Solid Waste Disposal, prepared for Utility Solid Waste Activities Group and Edison Electric Institute, July 1979.

28 Dames & Moore, "Review of Existing Literature & Published Data to Determine if Proven Documented Cases of Danger to Human Health and the Environment Exist as a Result of Disposal of Fossil Fuel Combustion Wastes", in Utility Solid Waste Activities Group (USWAG), Report and Technical Studies on the Disposal and Utilization of Fossil-Fuel Combustion By-Products, October 26, 1982, Appendix B.

29 Cherkauer, D. S. "The Effect of Fly Ash Disposal on a Shallow Ground-Water System." Ground Water, Vol. 18, No. 6, pp. 544-550, 1980.

30 Groenewold, G. H., and B. W. Rehm. "Applicability of Column Leaching Data to the Design of Fly Ash and FGD Waste Disposal Sites in Surface- Mined Areas." In Proceedings of the Low-Rank Coal Technology Development Workshop, comp. Energy Resources Company, Inc., DOE/ET/17086-1932, CONF-8106235; Washington, D.C., U.S. Department of Energy, Technical Information Center, pp. 3-79 - 3-95, 1981.

31 Envirosphere Company, Environmental Settings and Solid-Residues Disposal in the Electric Utility Industry; prepared for the Electric Power Research Institute, August 1984.

32 Linda Aller, Truman Bennet, Jay H. Laher, Rebecca J. Betty, A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrologic Settings, prepared by the National Well Water Association for U.S. EPA Office of Research and Development, Ada, OK, May 1985. EPA 600-285-018.

33 Veronica T. Pye, Ruth Patrick, John Quarles, Ground Water Contamination in the United States, Philadelphia: University of Pennsylvania Press, 1983.

34 Ground water over 180 ppm $CaCO_3$ may also be treated. Of the 34 percent of the sites in the sample that have public water systems in the plume downgradient from the site within 5 kilometers, 73 percent have ground water with a hardness over 180 ppm $CaCO_3$. Therefore, only 9 percent of the sites in the sample have both public water systems within 5 kilometers and ground water under 180 ppm $CaCO_3$. Since many public water systems may not treat water in the range of 180-240 ppm $CaCO_3$, the discussion in the report focuses only on ground water in excess of 240 ppm $CaCO_3$. This is a conservative assumption since the water may be treated, either by the public authority or the private homeowner. In all cases, the extent of exposure through private wells would have to be evaluated on a site-by-site basis.

CHAPTER SIX

ECONOMIC COSTS AND IMPACTS

Section 8002(n) of RCRA requires that EPA's study of coal combustion wastes examine "alternatives to current disposal methods," "the costs of such alternatives," "the impact of those alternatives on the use of coal and other natural resources" and "the current and potential utilization of such materials." In response to these directives this chapter examines the potential costs to electric utilities if coal-fired combustion waste disposal practices are regulated differently than they are currently.

The first section of this chapter (Section 6.1) examines the costs incurred by electric utilities using current disposal methods for coal combustion wastes.[1] Section 6.2 follows with a discussion of the costs that could be incurred if coal combustion wastes were regulated differently than they are today. These costs include the costs of implementing alternative waste management practices and the costs of additional administrative responsibilities that would be incurred. Section 6.3 examines how new regulations might affect the cost of utilizing coal combustion wastes in various by-product applications. The last section of this chapter (Section 6.4) considers how energy use patterns in the electric utility industry might change if alternative waste management practices that significantly affect the cost of generating electricity with coal were imposed.

6.1 WASTE DISPOSAL COSTS ASSOCIATED WITH CURRENT DISPOSAL METHODS

The management of utility wastes comprises a series of activities -- from initial waste collection to disposal. These current waste management activities can be classified into five basic components:[2]

1. **Waste Handling and Processing.** This is the initial phase of the disposal process, involving collection of the various waste products after they have been generated and initial treatment of the wastes to prepare them for final disposal.

2. **Interim Waste Storage at the Plant.** Some waste products that are dry when produced, such as fly ash or flue gas desulfurization (FGD) wastes from dry scrubbers, often require interim storage prior to final disposal.

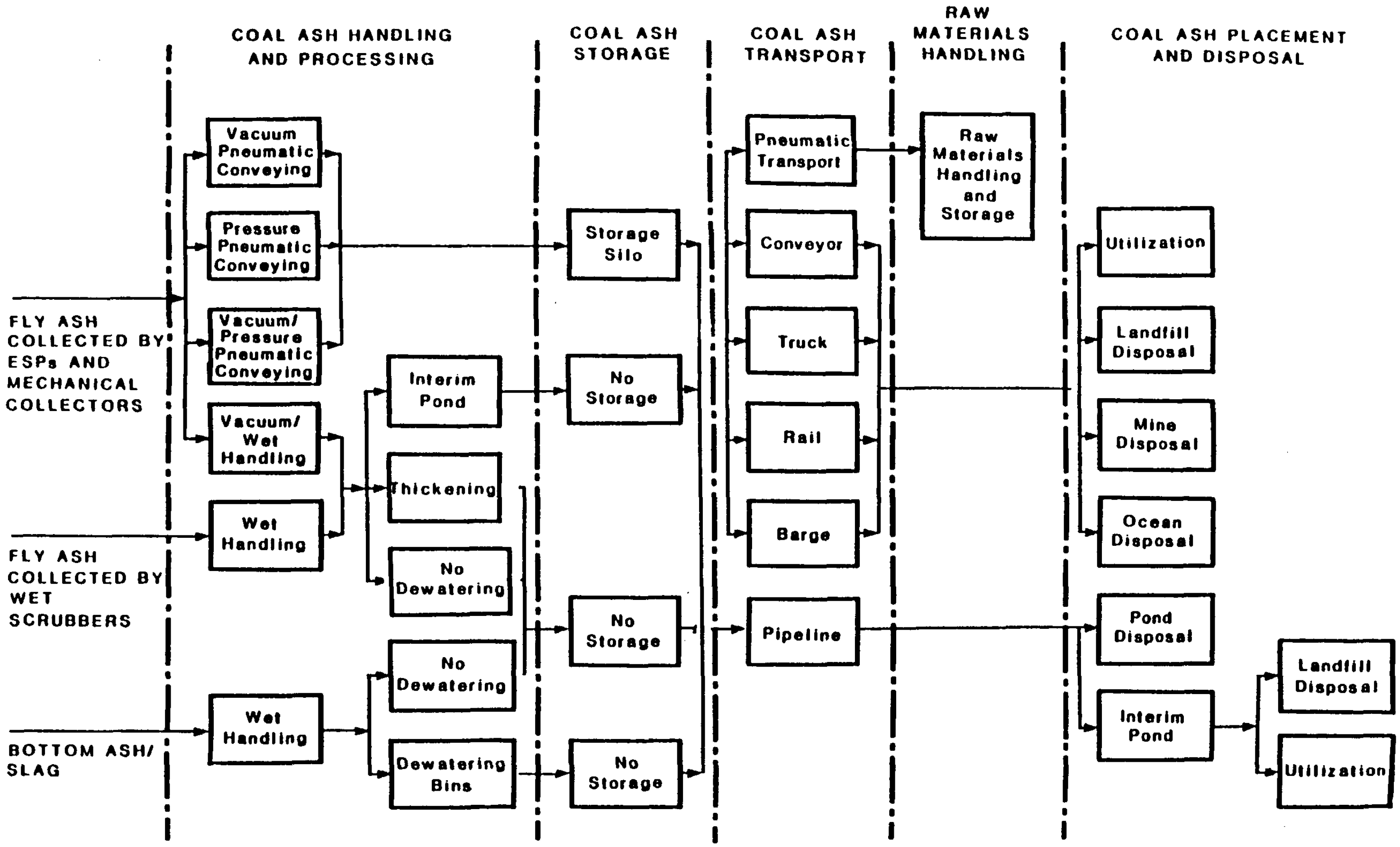
3. **Raw Materials Handling and Storage.** Some disposal processes involve stabilization or chemical fixation of the waste to prepare it for disposal. The raw materials used for this phase, including additives such as lime, Calcilox, and basic fly ash, often require special handling and storage facilities.

4. **Waste Transport to a Disposal Facility.** Environmentally sound disposal requires careful transportation of the waste to the disposal site. Many modes of transportation can be used, including trucks, railroads, barges, pipelines, and conveyor systems.

5. **Waste Placement and Disposal.** This is the final stage of the waste disposal chain. It involves placing the waste in a suitable waste management facility (usually a surface impoundment or landfill) and all activities required after the facility is closed. Alternatively, the final disposition of a waste product may entail utilization of the waste in various applications (such as cement production or sandblasting operations).

Exhibit 6-1 presents a schematic illustration of the current waste management and disposal options for coal ash; Exhibit 6-2 illustrates the options available for FGD wastes. The waste management costs discussed in this

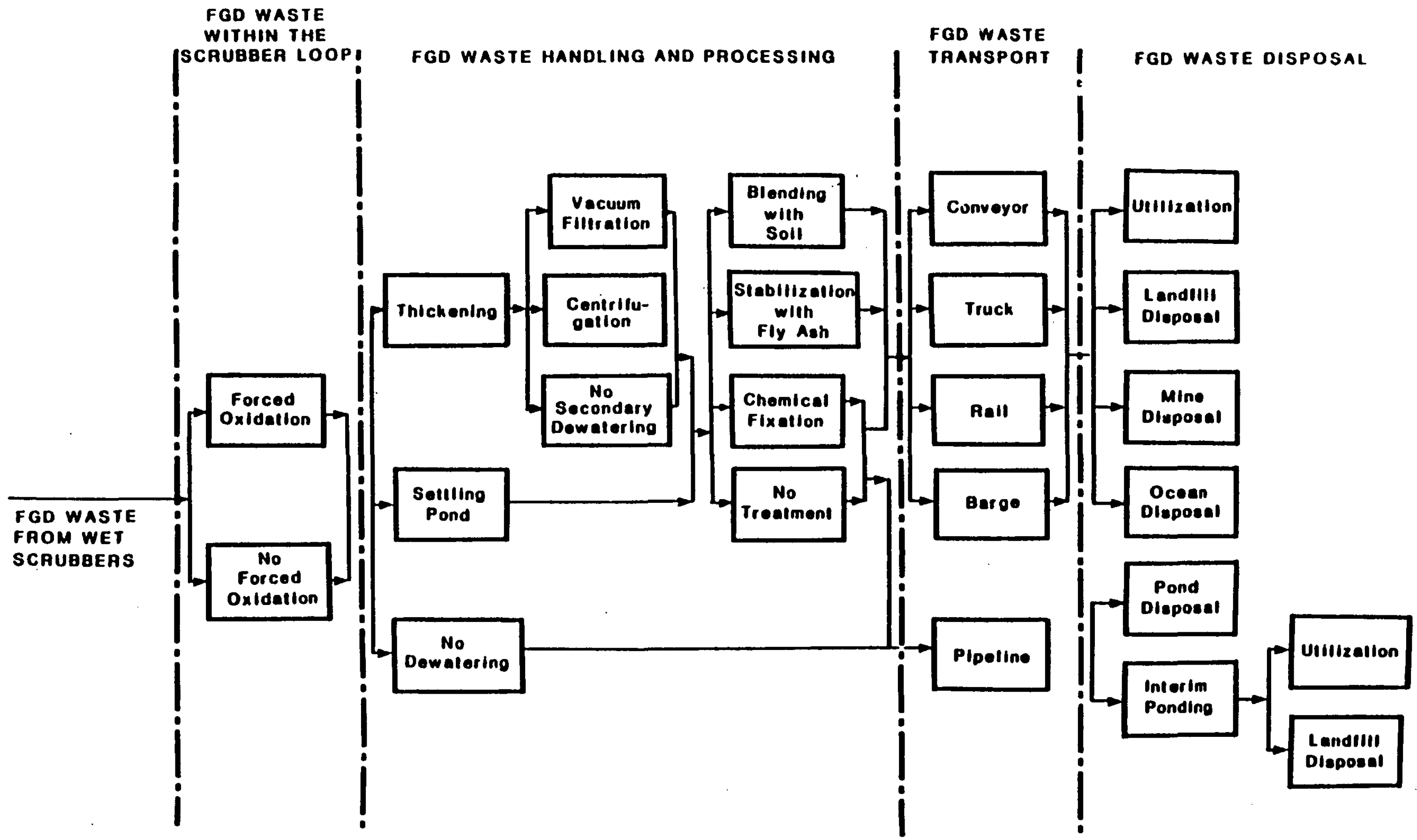
Exhibit 6–1
Overview of Waste Handling and Disposal Options for Coal Ash



Source: Arthur D. Little, Inc., *Full–Scale Field Evaluation of Waste Disposal From Coal–Fired Electric Generating Plants*, June 1985.

Exhibit 6-2

Overview of Waste Handling and Disposal Options for FGD Waste



Source: Arthur D. Little, Inc., *Full-Scale Field Evaluation of Waste Disposal From Coal-Fired Electric Generating Plants*, June 1985.

chapter are those associated with the last component of waste management (i.e., waste placement and disposal). These are the costs associated with actual construction of the waste management facility and placement of the wastes into the facility. If current practices for managing coal-fired wastes from electric utilities are altered, it is this final stage in waste management that would probably be most affected. However, as will be explored later in this chapter, some regulatory alternatives may affect other aspects of waste management.

6.1.1 Costs of Waste Placement and Disposal

The wastes from coal-fired combustion at electric utility power plants are often mixed together in the same waste management facility, typically a surface impoundment or landfill. Although surface impoundments were once the preferred method, and are still widely used, landfilling has become the more common practice because less land is required, and it is usually more environmentally sound (because of the lower water requirements, reduced leaching problems, etc.).

The costs of waste disposal can vary substantially. Exhibit 6-3 shows representative capital costs associated with constructing surface impoundments and landfills for coal-fired electric utility wastes. Exhibit 6-4 shows total costs (i.e., annualized capital costs plus operation and maintenance expenses).[3] Costs are shown for power plants that range in size from 100 to 3000 megawatts (Mw); power plants that fall outside of this range may incur

EXHIBIT 6-3

RANGES OF AVERAGE CAPITAL COSTS ASSOCIATED WITH COAL-FIRED ELECTRIC UTILITY WASTE DISPOSAL (4th quarter 1986 dollars per kilowatt)

	Size of Power Plant			
Type of Waste	100 MW	500 MW	1000 MW	3000 MW
Landfills				
Fly Ash	9-14	4-7	3-5	2-3
Bottom Ash	2- 5	2-3	1-2	1-1.3
FGD Waste	6-13	4-7	3-6	2-4
Surface Impoundments				
Fly Ash	27-50	15-27	13-23	10-18
Bottom Ash	10-20	6-11	5- 9	3- 6
FGD Waste	14-30	10-19	9-17	7-14

Source: Arthur D. Little, Inc., Full-Scale Field Evaluation of Waste Disposal From Coal-Fired Electric Generating Plants, EPA 600/7-85-028, June 1985.

EXHIBIT 6-4

RANGES OF AVERAGE TOTAL COSTS FOR COAL-FIRED ELECTRIC UTILITY WASTE DISPOSAL (4th quarter 1986 dollars per ton)*

Type of Waste	Size of Power Plant 100 MW	500 MW	1000 MW	3000 MW
Landfills				
Fly Ash	9-18	6-11	5-9	2-6
Bottom Ash	10-16	5-9	4-8	2-6
FGD Waste	4-10	4-7	3-6	2-4
Surface Impoundments				
Fly Ash	17-31	9-17	8-14	5-8
Bottom Ash	11-26	8-15	7-13	5-8
FGD Waste	8-17	7-13	6-10	5-7

* Dollar per ton estimates are based on the amount of waste produced each year. For purposes of this illustration, a power plant is assumed to generate annually 308 tons of fly ash per megawatt (MW), 77 tons of bottom ash per MW, and 264 tons of FGD waste per MW. Amounts will vary depending on coal quality, FGD technology, and boiler type, among other factors.

Source: Arthur D. Little, Inc., Full-Scale Field Evaluation of Waste Disposal From Coal-Fired Electric Generating Plants, EPA 600/7-85-028, June 1985.

different waste management costs. Both capital costs and total costs are shown for unlined facilities without ground-water monitoring or leachate control systems. The major factors affecting the cost of waste management are discussed below.

The amount of capital costs for a waste management facility can be attributed primarily to three factors: site preparation, excavation, and construction of containment structures.[4] Capital costs can be substantially reduced if the amount of earthwork can be minimized. Capital costs for surface impoundments, for example, increase significantly if dike construction or excavation is required. However, if existing site features can be used, such as valleys or abandoned pits, capital costs will be lower. Similarly, capital costs for landfills that require little excavation are lower than for those sites requiring extensive earthwork.

As Exhibit 6-3 illustrates, landfills are far less capital intensive than surface impoundments. For example, capital costs for fly ash placement in a surface impoundment at a 500 MW power plant would range from approximately $15 to $27 per kilowatt.[5] In contrast, capital costs for landfills range from about $4 to $7 per kilowatt. Landfills tend to cost less than impoundments primarily because the area required for a given amount of waste is less, and neither dikes nor piping and pumping systems are necessary.

Annual costs for landfills (see Exhibit 6-4) also tend to be less than those for surface impoundments primarily because landfills tend to be far less capital intensive. For example, costs for fly ash management at a 500 MW power plant range from about $9 to $17 per ton when the wastes are placed in surface impoundments, while the comparable range at a landfill is about $6 to $11 per ton. Similarly, the cost for bottom ash disposal at an impoundment for a 500 MW power plant ranges from $8 to $15 per ton, while the costs to dispose in a landfill range from about $5 to $9 per ton.

Other factors that affect the cost of utility waste disposal include

- **Size of the Power Plant.** Because larger power plants consume more coal than smaller facilities, they generate more waste material. However, more efficient operating procedures allow a larger disposal site to realize economies of scale not available at smaller sites; thus, the cost per ton of waste disposed is typically less.

- **Rate of Operation.** The number of hours that a coal-fired power plant operates varies from plant to plant, ranging from fewer than 3,500 hours per year to more than 6,500 hours. As operating levels increase, the amount of waste generated will increase as more coal is burned to meet the higher generation load.

- **Type of Coal.** The quantity of ash produced is proportional to the ash content of the coal, which ranges from 5 to 20 percent on average. Also, the grade of coal and boiler design will affect the relative proportions of fly ash and bottom ash (see Chapter Three for a discussion of the impact of boiler design on types and amount of wastes generated).

- **FGD Equipment.** Because of the additional materials used in flue gas desulfurization, a power plant that uses this process to remove sulfur dioxide generates substantially more waste than does a power plant with no sulfur dioxide controls. The amount of waste generated also varies from one FGD operation to the next, primarily because of differences in sulfur content among the various coals and, to a lesser extent, because of the type of FGD process employed.

For the few power plants currently disposing their waste in mines or quarries, this disposal method has been economic because of convenient access to the disposal site. Since much of the excavation normally required at a disposal site has already been performed as a result of the mining or quarrying operation, waste disposal costs can be quite competitive with costs associated with more traditional methods of disposal. The cost of disposing in mines or quarries for power plants that do not have easy access to the mine or quarry could quickly become prohibitive due to the costs of arranging for disposal at a remote site and of transporting the waste. Costs are also affected by whether or not the mine or quarry is still operating, whether the mining was surface or underground, and the amount of additional preparation required to dispose of the wastes, among other factors.

The costs of ocean disposal are not well known because there has been limited experience with this disposal method. Ocean disposal has been considered for <u>unconsolidated waste</u> (i.e., waste material that has not been physically or chemically altered prior to disposal)[6] and for more stabilized forms of waste, such as blocks for artificial reef construction;[7] however, this method has been attempted only for projects such as artificial reef construction, and then only on a trial basis. The most critical factors that would affect the magnitude of costs for ocean disposal are the availability of ash-handling facilities to load ocean-going vessels, the ability to gain easy access to the necessary waterways, and the physical characteristics of the wastes intended for disposal.

Because neither ocean disposal nor mine or quarry disposal is likely to be used on a widespread basis, they have been discussed here only briefly; see Chapter Four for a more detailed discussion of these two disposal options.

6.1.2 Costs Associated with Lined Disposal Facilities

The waste management costs presented above for surface impoundments and landfills do not include the cost of natural or synthetic liners to control the flow of leachate from the disposal area. Traditionally, most waste management sites, both surface impoundments and landfills, have not been lined to retard leaching, although this practice has become more widespread in recent years (see Chapter Four for a detailed discussion of liners). Currently, about 25 percent of all coal combustion waste management sites employ some type of liner system. Most liners are made of clay, synthetic materials, or stabilized utility waste.

Clay is used as a liner material because it is not very permeable, although its permeability will vary depending on the nature of the clay and the degree of compaction. Because clay is expensive to transport, the costs of the various clays used for liner material are directly related to the local availability of the clay. The installed cost of clay liners can range from $4.45 to $15.75 per cubic yard.[8] For a liner 36-inches thick, (liner thicknesses do vary), this results in a cost range of $21,000 to $75,000 per acre, or about $0.70 to $2.55 per ton of waste disposed in a landfill and $2.25 to $8.20 per ton for waste placed in an impoundment for a 500 MW power plant.[9]

Synthetic liner materials come in two basic varieties--exposable and unexposable. The membranes of exposable liners are resistant to degradation from exposure to the elements even if the liner is left uncovered. The membranes of unexposable liners will not function properly if the liner is exposed. Costs for installing exposable liners range from $43,000 to $113,000 per acre, or $1.45 to $3.85 per ton of waste disposed in landfills and from

$4.70 to $12.35 per ton of waste placed in surface impoundments.[10] Costs to install unexposable liners range from $59,000 to $123,000 per acre, or $2.00 to $4.15 per ton of waste disposed in landfills and $6.45 to $13.45 per ton placed in impoundments.[11] The ranges of costs are due primarily to differences in the cost of the material, differences in liner thickness, and allowances for various site-specific costs.

Stabilized utility waste, made from combinations of various ash wastes (such as fly ash or bottom ash), FGD waste, and lime, may be used as liner material when the required materials are available at the plant site. At an installed cost of about $13.70 per cubic yard, liners ranging from 3 feet to 5 feet in thickness can be constructed for $66,000 to $110,000 per acre,[12] which corresponds to total capital costs of $3.0-$5.0 million at a landfill, or about $2.25 to $3.75 per ton of disposed waste from a 500 Mw power plant. Total capital costs at impoundments would be $9.6-$16.0 million, or $7.20-$12.00 per ton of waste managed.[13]

6.2 COSTS OF ALTERNATIVE DISPOSAL OPTIONS

As described above, coal-fired utility wastes are currently exempt from RCRA Subtitle C waste management requirements. In the interim, coal combustion wastes are regulated under state statutes and regulations (see Chapter Four). If these wastes are subject to Subtitle C regulation, the incremental costs will depend on the regulatory option(s) ultimately selected. Section 6.2.1 outlines the major regulatory alternatives and discusses the flexibility allowed EPA under RCRA to promulgate regulations that account for the special nature of coal combustion wastes. Section 6.2.2 presents cost estimates for individual

Subtitle C disposal requirements, and Section 6.2.3 presents cost estimates for three regulatory scenarios if coal combustion wastes are regulated under Subtitle C.

6.2.1 Regulatory Alternatives under Subtitle C

As described in Chapter Five, there are two ways in which coal combustion wastes could be identified as hazardous and thus subject to requirements outlined in Part 264 of RCRA: the characteristic procedure and the listing procedure.

- **Regulation As Characteristic Waste.** Unless otherwise exempted, solid wastes are hazardous under RCRA if they display any of four characteristics: ignitibility, corrosivity, reactivity, or EP toxicity. Coal combustion wastes are unlikely to be ignitable or reactive, but could be corrosive (for aqueous wastes) or EP toxic. Subtitle C regulations would apply only to those waste streams that exhibited any of the hazardous characteristics. As discussed in Chapter Five, it is likely that only a small percentage of all waste generated would be hazardous. However, since some low volume wastes may be corrosive, this could have an impact on utilities that currently co-dispose high- and low-volume wastes. In these cases, the utility could either stop co-disposing or the landfill would have to conform to Subtitle C standards. In the case of surface impoundments, it might still be possible to co-dispose high- and low-volume wastes if the disposal impoundment met the requirements for a neutralization surface impoundment as set forth in 47 FR 1254, January 11, 1982.

- **Regulation as Listed Waste.** In addition to regulation under Subtitle C as characteristic waste, the Administrator may list a waste as hazardous under RCRA if it meets any of the three criteria contained in 40 CFR 261.11: (1) the waste exhibits any of the four characteristics described above; (2) it has been found to be fatal to humans in low doses or is otherwise measured as acutely hazardous; or (3) it contains any of the toxic constituents listed in Appendix VIII of Part 261. The Administrator does not have to list a waste that contains any of the toxic constituents listed in Appendix VIII if the Agency concludes that "the waste is not capable of posing a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise managed". The Administrator could decide to list as hazardous all coal combustion waste streams or only selected ones.

If Subtitle C regulation is warranted for coal combustion wastes, all the requirements for hazardous waste treatment, storage, disposal, and recycling facilities in 40 CFR 264 could be applied to the wastes from coal-fired power plants. Since coal combustion waste is mainly managed in surface impoundments and landfills, the requirements of Subparts A-H, K, and N would apply. In general, the required activities include the following:

- **General Facility Standards.** Facilities must apply for an identification number, prepare required notices when necessary, perform general waste analysis, secure the disposal facility to prevent unauthorized entry, comply with general inspection requirements, provide personnel training, and observe location standards (these include a provision that facilities located in a 100-year flood plain must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by a 100-year flood). (40 CFR 264 Subpart B)

- **Preparedness and Prevention.** Hazardous waste facility operators must design and operate facilities to minimize the possibility of fire or explosion, equip the facility with emergency equipment, test and maintain the equipment, and provide EPA and other government officials access to communications or alarm systems. (40 CFR 264 Subpart C)

- **Contingency Plan and Emergency Procedures.** The facility operators must have a contingency plan to minimize hazards to human health or the environment in the event of fire or explosion. (40 CFR 264 Subpart D)

- **Manifest System, Recordkeeping, and Reporting.** Hazardous waste facility operators must maintain a manifest system, keep a written operating record, and prepare a biennial report. (40 CFR 264 Subpart E)

- **Ground-water Protection.** Unless a waste management facility meets certain standards,[14] a Subtitle C facility is required to comply with requirements to detect, characterize, and respond to releases from solid waste management units at the facility. These requirements include ground-water monitoring and corrective action as necessary to protect human health and the environment. (40 CFR 264 Subpart F)

- **Closure and Post-closure.** Subtitle C facilities must comply with closure and post-closure performance standards to minimize the risk of hazardous constituents escaping into the environment. (40 CFR 264 Subpart G)

- **Financial Requirements.** Subtitle C facilities must establish a financial assurance plan for closure of the facility and for post-closure care. Possible methods of financial assurance include a closure trust fund, surety bonds, closure letter of credit, closure insurance, or financial test and corporate guarantee.[15] (40 CFR 264 Subpart H)

- **Design and Operating Requirements.** Unless granted an exemption, new surface impoundments or landfills or new units at existing impoundments or landfills must install two or more liners and a leachate collection system between the liners. (40 CFR 264 Subparts K and H)

In recognition of the special nature of coal combustion wastes, Congress afforded EPA some flexibility in designing regulations for coal combustion wastes if they are subject to regulation under Subtitle C. This flexibility allows EPA to exempt electric utilities from some regulations imposed on owners and operators of hazardous waste treatment, storage, and disposal facilities by the Hazardous and Solid Waste Amendments of 1984. Specifically, section 3004(x) of RCRA allows the Administrator to modify the following requirements when promulgating regulations for utility waste.

- Section 3004 (c) prohibits the placement of uncontained liquids in landfills;
- Section 3004 (d) prohibits the land disposal of specified wastes;[16]
- Section 3004 (e) prohibits the land disposal of solvents and dioxins;
- Section 3004 (f) mandates a determination regarding disposal of specified wastes into deep injection wells;
- Section 3004 (g) mandates determinations on continued land disposal of all listed hazardous wastes;
- Section 3004 (o) lists minimum technical requirements for design and operation of landfills and surface impoundments, which specify the installation of two or more liners, a leachate collection system, and ground-water monitoring;
- Section 3004 (u) requires the Administrator to promulgate standards for facilities that burn hazardous waste as fuel; and
- Section 3005 (j) provides that interim-status surface impoundments must also meet minimum technical requirements specified in section 3004 (o).

In addition to the flexibility afforded by 3004 (x), it is possible for EPA to modify any of the standards applicable to waste treatment and disposal facilities if lesser standards are protective of human health and the environment. Section 3004 (a) states "... The Administrator shall promulgate regulations establishing such performance standards, applicable to owners and operators of facilities for the treatment, storage, or disposal of hazardous waste identified or listed under this subtitle, as may be necessary to protect human health and the environment."

There remains substantial uncertainty, however, about the extent to which, in practice, the statutory language of Subtitle C would provide sufficient flexibility to design a waste management program appropriate for high-volume, low-toxicity coal combustion wastes. EPA may also consider waste management requirements, as needed, under the current Subtitle D provisions for solid wastes, or may seek appropriate additional authorities.

6.2.2 Cost Estimates for Individual RCRA Subtitle C Disposal Standards

If EPA determines that Subtitle C regulation is warranted for coal combustion wastes, there is a wide range of regulatory options that could be undertaken. Required activities could consist of some, all, or variations of the requirements listed in 40 CFR Subparts B-H (and described briefly in Section 6.2.1). This section presents estimates for the costs that would be associated with compliance with individual Subtitle C requirements.

6.2.2.1 General Facility Standards; Preparedness and Prevention; Contingency Plan and Emergency Procedures; and Manifest System

Subparts B through E in Part 264 of the RCRA regulations list general requirements for such activities as preparing written notices and plans for submission to EPA; conducting waste analyses; providing security at the disposal site; and recordkeeping and reporting. Many of these activities would be undertaken during the permitting process, which is set forth in Part 270 of RCRA.

The Part B application must contain the technical information listed in Part 264 B through E. The cost to the electric utility industry to prepare a Part B permit application was estimated in a study done for the Utility Solid Waste Activities Group (USWAG), which calculated that the total cost of submitting

Part B permit analyses would be $721,000 per plant, or about $0.55 per ton of waste disposed.[17] The industry cost, if all power plants filed Part B applications, would be about $370 million, or about $54 million in annualized costs.

Location standards are also specified under Subpart B of Part 264 of RCRA. One such standard is for facilities located in a 100-year flood plain. Part 246.16(b) requires protective measures to prevent washout from flooding.

USWAG estimated the costs for protecting waste disposal facilities located within a 100-year flood plain to be about $740 per acre for surface impoundments and about $1,100 per acre for landfills on an annualized basis.[18] This corresponds to waste management costs of approximately $0.55 per ton of waste at surface impoundments and $0.25 per ton at landfills.[19] Industry-wide costs for flood protection at all impoundments are estimated to be about $92 million for capital expenditures (about $13 million in annualized costs); costs for flood protection at all landfills would be about $146 million for capital expenditures (about $20 million in annualized costs).[20]

6.2.2.2 Ground-water Protection

Subpart F of 40 CFR Part 264 lists requirements for ground-water monitoring systems. The costs of installing and maintaining an acceptable ground-water monitoring program are dependent on the number of monitoring wells required and the frequency of testing. The study conducted by Arthur D. Little for EPA estimated that capital costs for installing six monitoring wells at a facility would range from $18,000 to $25,000.[21] At a sampling frequency of four times per year, annual operating and maintenance costs would be $10,000 to $14,500. Total ground-water monitoring costs would range from $0.06 to $0.10 per ton of managed waste. In another study conducted for USWAG by Envirosphere, which used different well configurations and cost parameters, somewhat higher costs ($0.10-$0.12 per ton of waste managed) were estimated.[22]

It is not known how many coal-fired power plants currently have adequate ground-water monitoring systems in place. To estimate industry-wide costs, EPA has conservatively assumed that all power plants would be required to install new ground-water monitoring systems. Using the costs developed in the Arthur D. Little study, EPA calculated that total capital costs would be about $9.3 to $12.8 million. Total annualized costs would range from $6.5 to $9.3 million.

6.2.2.3 Corrective Action

Subpart F of 40 CFR Part 264 also lists requirements for corrective action. A variety of actions may be undertaken to correct ground-water contamination problems caused by a hazardous waste disposal facility. The facility owner or operator would need to conduct a site-specific investigation to ascertain the potential degree of contamination and the appropriate response that would be most effective in remedying the situation. Types of remedial responses that might be required would be placing a cap (made of either a clay or synthetic material) on the disposal unit, counter-pumping the ground water to retard contaminant migration, excavating the disposal area and removing the wastes to a Subtitle C landfill, or installing an impermeable curtain around the disposal area to prevent ground-water flow into or out of the disposal area. As one example of the potential magnitude of corrective action costs, this section evaluates the cost to excavate the existing disposal areas and transfer the wastes to RCRA Subtitle C-approved facilities.

EPA developed the following formula to calculate total excavation costs for Subtitle C units, (including closure of the existing site and removal of the wastes to a Subtitle C facility):

$$\text{Cost} = [(\text{Surface Area} \times \$45) + (\text{Volume} \times \$187)] \times 2.16$$

where the surface area is measured in square meters, and volume is measured in cubic meters.[23]

For a power plant of average size (500 MW), it has been assumed that a 45-acre landfill would be required, or about 182,000 square meters, with a capacity of approximately 5 million cubic meters. Based on the cost equation listed above, costs for excavation and waste transfer for a landfill site would be about $2.0 billion.[24] For surface impoundments, the appropriate parameters are 145 acres, or about 587,000 square meters, and a volume of about 5 million cubic meters, which works out to about $2.1 billion for the same type of corrective action. If this type of corrective action were required at all power plants, compliance costs for the industry would be enormous. At a cost of about $2 billion per plant, industry-wide costs would exceed one trillion dollars.

6.2.2.4 Closure and Post-closure

Subpart G of 40 CFR 264 specifies general closure and post-closure requirements for Subtitle C facilities and 40 CFR 264(K) and (N) list specific requirements for closure and post-closure care of surface impoundments and landfills, respectively. These requirements, as applied to coal combustion wastes, would require the dewatering of ash ponds, installation of a suitable cover liner made of synthetic materials, application of topsoil to support vegetation, seeding and fertilizing, installation of security fencing, and long-term ground-water monitoring. USWAG estimates that capital costs for closing a waste management facility range from $39,000 to $128,000 per acre for surface impoundments and from $55,000 to $137,000 per acre for landfills.[25] Once the facility is closed, additional costs would be incurred for post-closure care -- about $1,050 per acre annually.[26] Total annual costs for closure of a surface impoundment would range from about $1.0 to $2.8 million for a typical 500 Mw power plant, or $5.00 to $14.75 per ton of waste managed. For a landfill, total annual costs would range from $0.4 to $0.9 million, or $2.10 to $4.90 per ton.[27].

An owner or operator that chooses to close a facility in the event that coal combustion wastes are brought under Subtitle C regulation would not necessarily have to follow the closure and post-closure requirements for hazardous waste facilities listed in 40 CFR Part 264. If regulations are proposed, there would be some period of time before final regulations take effect.[28] If the disposal facility is closed during this interim period, the closure standards that would apply would be those required under state regulations, not Subtitle C regulations.

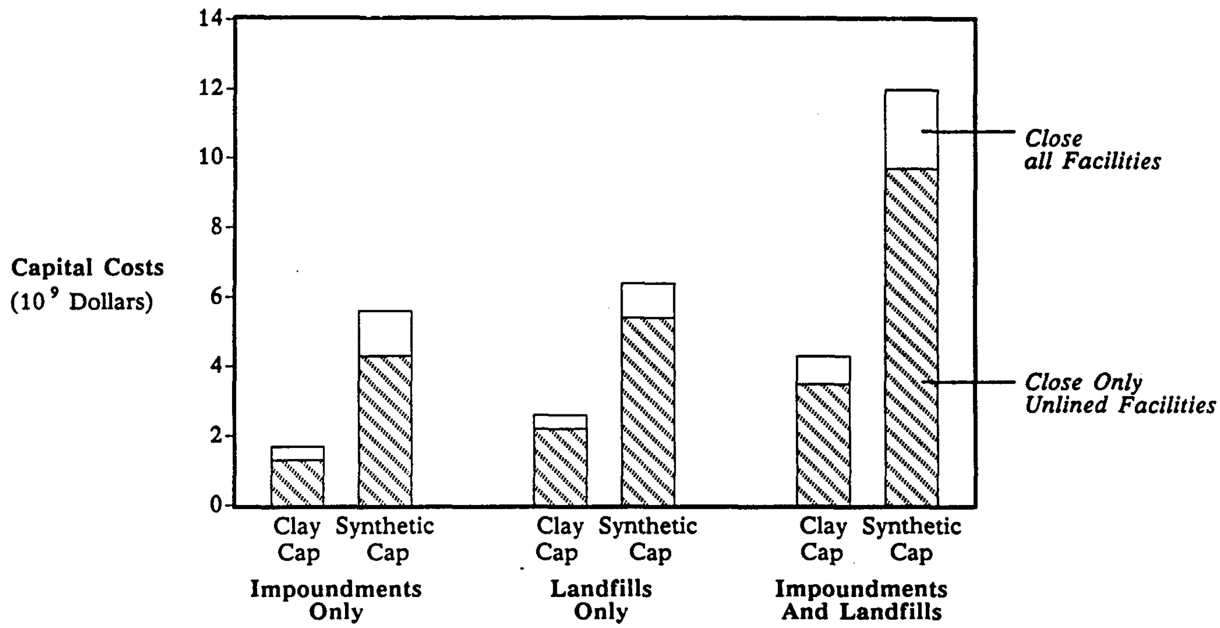
A facility that closes after the new regulations take effect, however, is subject to Subtitle C closure and post-closure requirements. The USWAG study provides an estimate of the total costs of closing all existing coal combustion waste disposal facilities and of the costs of closing only unlined facilities (See Exhibit 6-5). Total capital costs required to close all unlined landfills and impoundments would range from $3.5 billion for clay-capped facilities to $9.7 billion for synthetic-capped facilities. If all facilities closed under Subtitle C regulation, total capital costs would be about $4.3 billion for clay-capped closure and $12.0 billion for synthetic-capped closure.[29] Total annualized costs to close only unlined facilities would range from about $575 million for closure with clay caps to about $1.5 billion for synthetic caps. If all current waste management facilities were closed, annualized costs would be about $700 million for clay caps to $1.8 billion for synthetic caps.

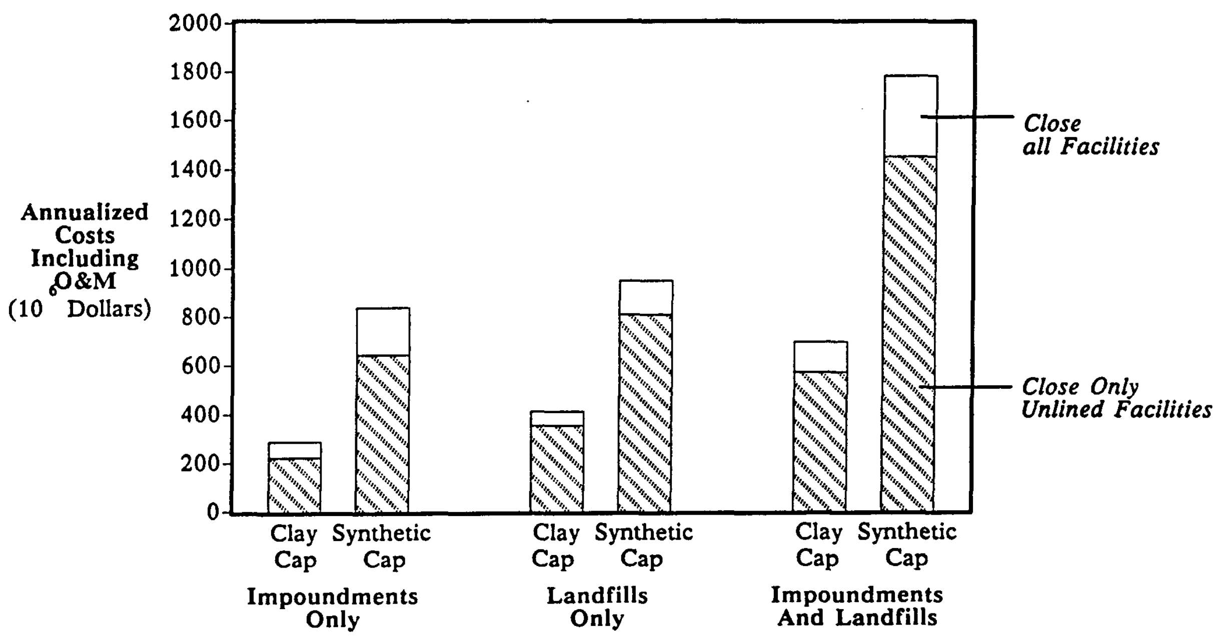
6.2.2.5 Financial Responsibility

Subpart H of 40 CFR 264 sets forth requirements for financial responsibility for closure and post-closure care of hazardous waste facilities. A facility owner may use several different financial mechanisms to demonstrate financial responsibility, including purchasing a letter of credit, posting a surety bond, establishing a trust fund, purchasing an insurance policy, providing a corporate guarantee, or passing a financial test. Financial responsibility could be required for closure/post-closure costs or corrective action costs. The magnitude of the costs can vary considerably depending on the financial mechanism that is used and the type of activity for which financial assurance is required. For example, costs to provide a corporate guarantee or pass a financial test may be on the order of a few hundred dollars per facility; on the other hand, annual costs to obtain a letter of credit or to establish a trust fund are often based on some percentage (e.g., one to two percent) of the total

EXHIBIT 6-5

**SUMMARY OF COSTS TO CLOSE
EXISTING WASTE DISPOSAL FACILITIES**





Source: Envirosphere Company, "Report on the Costs of Utility Ash and FGD Waste Disposal," in USWAG, *Report on the Costs of Utility Ash and FGD Waste Disposal,* Appendix F Part 2, October 19, 1982.

costs of the closure/post-closure or corrective action activity to be undertaken.[30]

6.2.2.6 Design and Operating Requirements for Landfills and Surface Impoundments

The level of effort required to come into compliance with Subtitle C design and operating requirements will depend on many site-specific considerations. In some cases, it may be possible to seal off the portion of the existing disposal site that has been in use and upgrade the remaining portion by installing a liner. In other situations the required changes may be sufficiently different from existing disposal practices that the most cost-effective action may be to open an entirely new disposal facility.

Given the variety of site-specific situations that may arise, and given the regulatory flexibility EPA has in designing coal combustion waste management standards, it is not feasible to estimate how many utility waste management facilities may be affected or what type of waste management measures may be required without conducting site-specific investigations. Nevertheless, to indicate the approximate magnitude of costs that may be involved for different waste management practices, the costs for three management options -- single-lined landfills, single-lined surface impoundments, and double-lined surface impoundments -- are presented below.

Landfills

As noted earlier, single clay liners can be installed in a landfill for about $0.70 to $2.55 per ton of disposed waste and single synthetic liners for about $1.45 to $4.15 per ton of disposed waste. The costs presented in Exhibit 6-4 indicate that waste disposal costs at a representative 500 Mw power plant with no flue gas desulfurization equipment would average about $5 to $11 per ton of disposed waste for a landfill operation. Adding a single clay liner to the landfill would increase total costs to $5.70 to $13.55 per ton of disposed waste; adding a single synthetic liner would increase costs to $6.45 to $15.15 per ton of disposed waste.

These estimates appear to be similar in magnitude, although somewhat lower than costs estimated in another study of utility waste disposal costs conducted for the Utility Solid Waste Activities Group (USWAG) by Econometric Research, Inc. That study estimated that total costs for complying with requirements related to the construction, operation, and maintenance of a single-lined landfill would range from about $15 to $24 per ton of waste, depending on the type of liner.[31]

The study for USWAG also analyzed the total costs to the electric utility industry if all power plants currently using landfills were required to construct new landfills with single liners. For this scenario, USWAG assumed that existing facilities, even if lined, would have to be replaced to comply with new requirements. Total capital costs for this alternative would range from $2.6 billion for landfills with one synthetic liner to $4.0 billion for landfills with a single clay liner.[32] Estimated annualized costs were about $400 million for installing a single synthetic liner at all landfills and about $600 million for installing a single clay liner.[33]

Surface Impoundments

The costs presented in Exhibit 6-4 for unlined surface impoundments indicated that waste managed at a representative 500 Mw power plant with no FGD waste production would cost about $8 to $17 per ton of waste. Using the cost estimates for liners noted earlier (see Section 6.1.2), adding a single clay liner would increase total management costs to about $10.25-$25.20 per ton of waste, and adding a synthetic liner would increase costs to $12.70-$30.45 per ton of waste.

These cost estimates for single-lined impoundments appear to be reasonably consistent with other estimates. Studies for USWAG indicated that management costs for impoundments with a single synthetic liner were about $19 per ton of waste and $30 per ton of waste for impoundments with a single clay liner.[34]

The USWAG report also estimated the total costs to the electric utility industry to construct new impoundments with single liners (i.e., all power plants currently using surface impoundments would be required to construct new facilities to meet disposal requirements even if the current impoundment is already lined). For this alternative total capital costs would range from $5.8 billion for impoundments with single synthetic liners to $9.5 billion for impoundments with single clay liners.[35] Annualized costs would range from $850 million for single synthetic liners at all impoundments to $1.4 billion for single clay liners.[36]

The study for USWAG also estimated management costs for surface impoundments with two different types of double liners -- a double synthetic liner (each with a 30 mil thickness) and a double liner system consisting of one synthetic liner (30 mil) and a clay liner (36 inches). Total management costs for double-lined surface impoundments would range from about $29 per ton of waste for a site with two synthetic liners to $36 per ton of waste for a site with one synthetic liner and one clay liner.[37]

Industry-wide costs were also estimated for the installation of new double-lined surface impoundments at all power plants currently using surface impoundments. Total capital costs for installing a double-lined impoundment ranged from $9.3 billion for a double synthetic liner to $11.6 billion for one clay and one synthetic liner.[38] Total annualized costs were estimated at $1.4 billion for all impoundments with a double synthetic liner and $1.7 billion for all impoundments with one clay liner and one synthetic liner. A summary of the costs for the various types of lined disposal facilities discussed herein is presented in Exhibit 6-6.

6.2.2.7 Summary of Costs for Various Waste Management Alternatives

Exhibit 6-7 summarizes the costs to the electric utility industry of each of the waste management options previously discussed. The exhibit presents cost estimates for the total amount of capital required for each waste management standard and for the total amount of annualized costs (i.e., annual capital, operation, and maintenance costs) that would be incurred in order to comply with each requirement if coal-fired combustion wastes were regulated as hazardous wastes.

EXHIBIT 6-6

SUMMARY OF COSTS FOR DIFFERENT TYPES OF LINED WASTE MANAGEMENT FACILITIES

	Cost per ton	Total Annual Costs for the industry a/ (millions of dollars)
Landfills		
Basic Practice--Unlined	$ 5.00-$11.00	N.A.
Single Clay Liner	$ 5.70-$13.55	600
Single Synthetic Liner	$ 6.45-$15.15	400
Surface Impoundments		
Basic Practice--Unlined	$ 8.00-$17.00	N.A.
Single Clay Liner	$10.25-$25.20	1,380
Single Synthetic Liner	$12.70-$30.45	865
Double Synthetic Liners	$29.00	1,360
Double Liners: 1 Synthetic and 1 Clay	$36.00	1,680

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a/ Total annual costs refer to annualized costs that capture capital, operation, and maintenance expenses. Since these costs were calculated by assuming that the utility industry would have to construct new facilities to comply with hypothetical alternative regulations, these costs are in addition to the current management costs incurred by the industry.

Source: Envirosphere Company, "Report on the Costs of Utility Ash and FGD Waste Disposal." In USWAG, Report and Technical Studies on the Disposal and Utilization of Fossil-Fuel Combustion By-Products, October 19, 1982.

Preparation of Part B Permit		
Construction of New Disposal Facilities		
Landfills		
- Single clay liner		
- Single synthetic liner	2.6	
Surface Impoundments		
- Single clay liner	9.5	1400
- Single synthetic liner	5.8	850
- Double liner		
- clay/synthetic	11.6	1700
- two synthetic	9.3	1400
Closure of Existing Disposal Facilities		
Only Unlined Facilities Close		
- Clay cap	3.5	575
- Synthetic cap	9.7	1500
All Facilities Close		
- Clay cap	4.3	700
- Synthetic cap	12.0	1800
Installation of Leachate Collection Systems	1.2	460
Provisions for Flood Protection		
Landfills	0.15	20
Impoundments	0.09	13
Ground-water Monitoring Systems	0.009-0.013	6-9
Excavate Existing Facilities, Removing Waste to Subtitle C Facilities	1028.0 a/	NA

a/ Costs shown are for capital, operation, and maintenance costs for the entire industry since the amount of capital required was not readily available.

A combination of compliance alternatives could occur (e.g., closing existing disposal facilities and constructing new facilities with leachate collection and ground-water monitoring systems). The actual cost to the electric utility industry for complying with RCRA Subtitle C requirements would depend on the regulatory actions taken by the Agency if the temporary exemption under Section 3001 of RCRA is removed. Three possible regulatory scenarios are discussed in the following section.

6.2.3 Potential Costs to the Industry of RCRA Subtitle C Waste Management

Section 6.2.2 presented cost estimates for individual regulatory requirements that could be imposed on utilities if EPA determines that Subtitle C regulation is warranted for coal combustion wastes. In this section, three possible regulatory scenarios are examined to quantify the range of incremental costs that could result from various regulatory options. In the first scenario, the incremental costs of regulating a portion of low volume wastes under Subtitle C are presented. The second scenario assumes that all coal combustion waste would be subject to Subtitle C requirements. The third scenario assumes that high volume coal combustion wastes would be tested for RCRA hazardous characteristics and that a small portion of the waste would be classified as Subtitle C characteristic waste. For all three regulatory scenarios, costs are shown only for bringing all existing power plants into compliance with the assumed RCRA Subtitle C management regulations.

Low Volume Waste Scenario

This scenario evaluates the costs to the utility industry if some low volume waste streams are classified as hazardous wastes under Subtitle C. As discussed in Chapter Three, some of these wastes can exhibit hazardous characteristics such as corrosivity. The information available to EPA at this time does not permit the Agency to quantify the amount of low volume wastes that may exhibit hazardous characteristics. In this scenario, EPA has assumed that all water-side boiler cleaning wastes are regulated as hazardous wastes since these waste streams may exhibit corrosive characteristics. These waste streams are assumed to be hazardous to provide an approximate estimate of the costs to the industry if some low volume wastes display RCRA hazardous characteristics. That is, both high-volume and low-volume wastes could be tested for RCRA hazardous characteristics, but only a small portion of the low-volume wastes (as represented by all water-side boiler cleaning wastes) would need to be treated as hazardous.

As shown in Exhibit 3-19, a representative power plant generates about 180,000 gallons per year of water-side boiler cleaning wastes. The cost to dispose of these wastes as hazardous liquids can vary depending on waste stream variability, regional differences in disposal costs, and quantity to be disposed, among other factors.[39] For purposes of this analysis, an incremental cost of $2 per gallon (including transportation) has been assumed based on a 1985 survey of hazardous waste management prices.[40] With 180,000 gallons generated per year at a representative power plant, annual disposal costs would be about $360,000 per power plant. Since there are 514 power plants in the U.S., annual disposal costs to the utility industry would be about $185 million.

Full Subtitle C Regulation Scenario

If EPA lists high volume coal combustion waste streams in 40 CFR 261.31-261.33, all utilities will be affected. Utilities would be required to manage all coal combustion wastes in Subtitle C permitted facilities. To estimate the incremental costs to the industry of this regulatory scenario, the Agency assumed that all utilities would close existing facilities and open new waste management facilities that complied with Subtitle C standards. This scenario assumes that the costs of managing wastes off-site will equal the costs of managing wastes on-site and that existing facilities would be closed in the six months before Subtitle C regulation took effect, thereby avoiding Subtitle C closure and post-closure requirements.

Under existing state regulations, a clay cap is assumed to be adequate to close existing waste management facilities. The total annual costs of closing all existing facilities with a clay cap would be $700 million. For the new facilities, EPA assumed utilities would prepare a Part B permit application, construct new landfills and surface impoundments with clay/synthetic double liners, install leachate collection systems, make provisions for flood protection, and install ground-water monitoring systems. To determine incremental costs for the industry, EPA assumed that the current proportions of waste management facilities that were landfills and surface impoundments would remain unchanged under Subtitle C regulation. As summarized in Exhibit 6-7, total annual costs of the new Subtitle C facilities would be $54 million for Part B permit applications, $725 million for new double lined landfills,[41] $1700 million for new double lined surface impoundments, $460 million for leachate collection systems, $33 million for flood protection, and $9 million for ground-water monitoring. Total incremental costs for this regulatory scenario would be $3.7 billion annually.[42]

High Volume Characteristic Waste Scenario

If coal combustion wastes were not exempt from RCRA Subtitle C regulation, utilities would have to test high-volume and low-volume coal combustion wastes for RCRA hazardous characteristics. Based on the RCRA characteristic results in Chapter Five, it appears that only a small portion of coal combustion wastes possess the hazardous characteristics of EP Toxicity or corrosivity. For purposes of this scenario, the Agency assumed that five percent of the wastes generated by utilities would need to be disposed in Subtitle C permitted facilities. The Agency does not have sufficient information to know exactly the amount of coal combustion waste that would exhibit RCRA hazardous characteristics. EPA believes that coal combustion wastes generally would not fail the RCRA hazardous characteristic tests. Based on limited information presented in Chapter Five that indicate about five percent of all ground-water observations at utility sites exceed the Primary Drinking Water Standards, the Agency assumed that five percent of all wastes would require Subtitle C treatment. The total annual cost to the industry if utilities close existing facilities and construct new double lined facilities for five percent of all coal combustion wastes would be $185 million.

6.3 IMPACT OF REGULATORY ALTERNATIVES ON UTILIZATION OF COAL COMBUSTION WASTES

As discussed in Chapter Four, coal-fired utility wastes have been used in a variety of applications by electric utilities and other industries to replace other types of material. The use of utility wastes as a replacement for other materials has reduced the amount of wastes utilities have had to dispose, while correspondingly reducing the resource requirements of other industries that have managed to find a productive use for the waste material.

In the event that some or all of these wastes were declared hazardous, it is possible that the amount of by-product utilization of coal-fired utility wastes would decline as a result of increased costs for their use and the potential for outright prohibition of their use in some applications. On the other hand, it is possible that certain forms of utilization (e.g., the use of fly ash in cement) may be deemed environmentally acceptable practices if the wastes would be unlikely to pose an environmental threat when used for such purposes. Since costs for other forms of disposal may increase, utilization may also increase. However, for discussion purposes, this section assumes that designation as a hazardous waste would tend to discourage by-product utilization.

The costs that would be incurred as a result of environmental concerns over the utilization of coal-fired utility wastes would depend on the regulatory requirements that would have to be followed to use the wastes. The more stringent the additional regulatory burden imposed, the greater the impact on by-product utilization due to the higher costs of using the wastes.

In the USWAG study referenced above, the potential range of costs associated with reduced use of coal combustion by-products was also evaluated. Three different regulatory scenarios were analyzed.[43]

- The transportation of coal-fired utility wastes is regulated as hazardous waste transportation under Subtitle C of RCRA; use or disposal of the wastes would not be regulated.
- All activities associated with reuse of coal combustion by-products is regulated, and the regulations affect both the transporter and owner/operator of a Subtitle C hazardous waste management facility.
- Reuse of coal combustion by-products is prohibited.

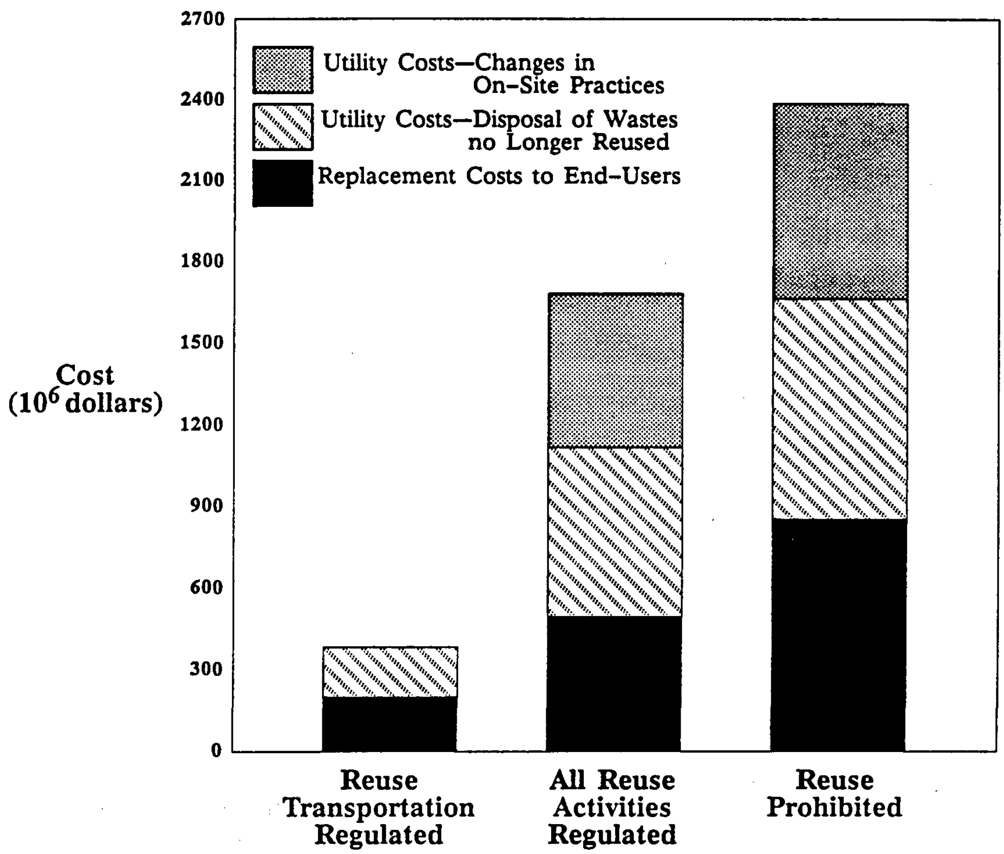
There would be three types of costs incurred under these regulatory scenarios: (1) replacement costs to the end-users who would no longer find it economic to utilize the coal combustion by-products, (2) costs to utilities to dispose of wastes no longer reused by other industries, and (3) additional costs to the utility industry for replacement and disposal of wastes that could no longer be used on-site. A summary of the costs associated with each scenario is provided in Exhibit 6-8.[44]

If the transportation of coal combustion by-products were subject to increased regulation under Subtitle C, the USWAG report estimated that the use of these by-products would decline by nearly 40 percent, increasing overall disposal volumes by about 8 percent.[45] The industries that would be affected the most would be the roofing granules industry (conventional roofing granules would replace bottom ash and boiler slag at a cost of about $115 million in annual costs) and the concrete industry (portland cement would replace fly ash at a cost of about $40 million in annual costs).[46]

If all activities pertaining to reuse of coal combustion wastes were subject to Subtitle C regulations, utilization of coal combustion

EXHIBIT 6-8

Summary of Economic Impacts on By-Product Utilization under Different RCRA Regulatory Scenarios*



*All costs are annualized based on impacts estimated from 1984-2000.

Source: USWAG, Report and Technical Studies on the Disposal and Utilization of Fossil-Fuel Combustion By-Products, Appendix G, October 26, 1982 by-products was estimated to decline by about 75 percent, increasing overall disposal volumes by about 14 percent.[47] The greatest impact would be on the concrete industry, which would spend about $270 million annually to replace fly ash with portland cement.[48]

If all reuse of coal combustion by-products were prohibited, industries using these by-products would have to find suitable replacements; total disposal volumes would increase by nearly 20 percent.[49] The largest impacts would be on the asphalt industry, which would be forced to replace ash with asphalt at a cost of approximately $250 million annually, and the concrete industry, which would replace fly ash with portland cement at a cost of about $270 million annually.[50]

6.4 ECONOMIC IMPACTS OF ALTERNATIVE WASTE DISPOSAL OPTIONS

Since many alternative disposal practices discussed in this chapter could impose additional costs on the electric utility industry, this section evaluates the effect that these increased costs might have on electricity generation costs and U.S. coal consumption. This study employs three measures to determine the potential economic impact of alternative disposal practices:

1. Average increase in electricity generation costs at existing coal-fired power plants,

2. Average increase in electricity generation costs at coal-fired power plants yet to be constructed, and

3. Impact on the electric utility industry's consumption of coal.

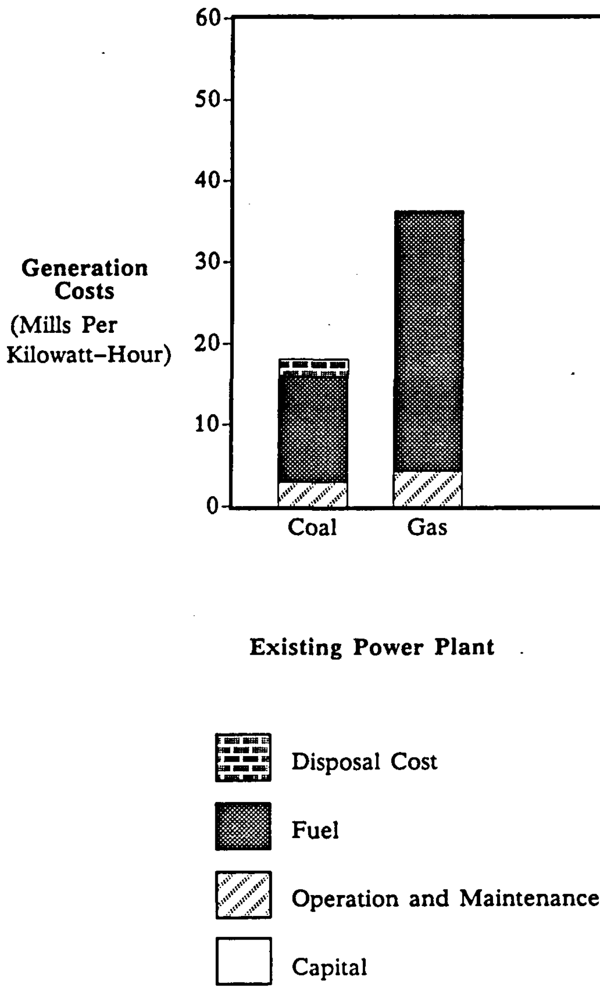
Exhibit 6-9 summarizes the cost of generating electricity at both existing and yet-to-be-constructed power plants (see Appendix G for a detailed discussion of the assumptions used to determine these generation costs).[51] Disposal costs average about 3-5 percent of total generation costs at existing coal-fired power plants, but only about 1-3 percent at future power plants. Although the actual costs of disposal at existing and future power plants are similar, the percentages are different because total generation costs at future power plants are higher than generation costs at existing power plants (resulting in a lower overall percentage for disposal costs at future power plants). Total generation costs are higher at future power plants because they include capital, operation and maintenance, and fuel costs, while the generation costs for existing power plants include operation and maintenance and fuel costs only.[52]
Based on the cost assumptions used to develop Exhibit 6-9, coal-fired electricity generation at both new and future baseload[53] power plants is less expensive than generation with natural gas.[54]

The economic impacts likely to result from the use of alternative coal-fired utility waste disposal practices will depend upon several factors, including which disposal options are required, how much the cost of coal-fired electricity generation changes, and whether these changes affect the relative competitiveness between coal and other fuels. To indicate the potential magnitude of these impacts, Exhibit 6-10 summarizes the potential cost impacts on electricity generation rates due to the alternative waste disposal options discussed earlier in this chapter.

As indicated in Exhibit 6-10, some alternative disposal options could

EXHIBIT 6-9

IMPACT OF CURRENT WASTE DISPOSAL COSTS ON TOTAL ELECTRICITY GENERATION COSTS*



* Generation costs are based on typical 500 Mw power plant in the midwest operating at 70 percent utilization rate. Regional costs will vary depending on fuel price and availability, among other factors.

Source: Generation cost estimates are from ICF Incorporated. Waste disposal costs are taken from Arthur D. Little, Inc., *Full-Scale Field Evaluation of Waste Disposal From Coal-Fired Electric Generating Plants.* June 1985.

EXHIBIT 6-10

IMPACT OF ALTERNATIVE DISPOSAL OPTIONS ON ELECTRICITY GENERATION COSTS

		Impact On Generation Costs		
	Incremental Cost		% of Total Generation Costs	
Option	($/ton of disposed waste)	mills/kilowatt-hour a/	Existing Plant	Future Plant
Part B Permit	$0.55	0.03	0.2	0.1
Existing Landfills b/				
Single Clay Liner	$0.70-$2.55	0.04-0.16	0.2-0.9	0.1-0.3
Single Synthetic Liner	$1.45-$4.15	0.09-0.26	0.5-1.4	0.2-0.6
Existing Surface Impoundments				
Single Clay Liner	$2.25-$8.20	0.14-0.51	0.8-2.8	0.3-1.1
Single Synthetic Liner	$4.70-$13.45	0.30-0.84	1.7-4.7	0.6-1.8
New Landfills				
Single Clay Liner	$ 5.70-$12.55	0.36-0.79	2.0-4.4	0.8-1.7
Single Synthetic Liner	$ 6.45-$15.15	0.40-0.95	2.2-5.3	0.9-2.0
New Surface Impoundments				
Single Clay Liner	$10.25-$25.20	0.64-1.58	3.6-8.8	1.4-3.4
Single Synthetic Liner	$12.70-$30.45	0.80-1.91	4.4-10.6	1.7-4.1
Double Synthetic Liner	$29.00	1.82	10.1	3.9
Double Synthetic/ Clay Liner	$36.00	2.26	12.6	4.8
Site Closure	$2.10-$14.75	0.13-0.93	0.7-5.2	0.3-2.0
Leachate Control	$4.70	0.30	1.7	0.6
Flood Protection	$0.25-$0.55	0.02-0.03	0.1-0.2	c/
Ground-water Monitoring	$0.06-$0.10	0.004-0.006	c/	c/
Utilization				
Transportation				
Regulated	$3.00	0.19	1.1	0.4
All Activities				
Regulated	$13.20	0.83	4.6	1.8
Reuse Prohibited	$18.75	1.18	6.6	2.5

a/ Based on a representative 500 Mw plant operating at a 70 percent utilization rate. Costs are incremental costs only; that is, cost impact of new disposal facilities is only that portion of costs in excess of current disposal costs (see Exhibit 6-4 for these costs). A mill is one-tenth of a cent ($0.001).

b/ Costs for existing waste disposal facilities refer only to the cost of liner installation. Costs for new waste disposal facilities refer to all the costs for site construction and liner installation.

c/ Less than 0.1 percent.

increase electricity generation costs at existing power plants by several percent. In some cases the cost impact could be substantial if several options were combined as part of an integrated waste management strategy. For example, if new waste management regulations led to closure of the current disposal site and the construction of a new lined facility with a leachate control system, flood protection, and ground-water monitoring system, coal-fired generation costs at existing coal-fired power plants could increase by nearly 20 percent (roughly 3.5 mills/kilowatt-hour).

Generation cost increases of this magnitude have the potential to reduce coal consumption at existing coal-fired power plants if these cost increases make it more expensive to generate electricity with coal than with other fuels. A utility decides how much electricity to generate at any existing power plant primarily by comparing the operation and maintenance costs (including fuel) associated with generating electricity at all of its power plants. Power plants with the lowest generation costs will be operated first. Generally, it is less expensive to generate electricity with coal than with other fuels such as oil or gas, but oil-fired electricity generation can be competitive with coal when the price of oil is approximately $10-$15 per barrel.[55] However, whether and to what degree electric utilities would shift away from the use of coal would depend on several factors, including the relative price of coal compared with the price of other fuels, the magnitude of the increase in generation costs if disposal practices were altered, and the overall efficiency of competing power plants.

For power plants yet to be constructed, the impact of higher disposal costs on coal consumption could be more substantial, with possible generation cost increases approaching 8-10 percent if several options are combined. Generation cost increases of this magnitude could have a substantial effect on the amount of coal consumed at future power plants since many utilities may decide not to build coal-fired power plants. Although currently coal-fired electricity generation may be a more economic option than oil-fired or gas-fired generation at plants yet to be constructed, this situation could change if more expensive disposal practices were required for coal combustion wastes. This is because the higher capital costs of coal-fired electricity generation, compared with oil- or gas-fired generation, reduces the overall cost differential between the use of coal and the use of oil or gas at future power plants (compared to the cost differential between coal and oil or gas at existing power plants). As a result, coal is more likely to be replaced by alternative fuels at future power plants than it is at existing power plants.

In fact, since oil prices dropped below $20 per barrel in early 1986, many utilities have been seriously evaluating the feasibility of building oil- or gas-fired generating capacity in lieu of coal-fired units. As a result, in some instances even an increase of a few percent in coal-fired generation costs could be sufficient to tip the balance in favor of using natural gas or oil to fuel power plants that have not yet been constructed. If increased disposal costs do promote such competition, growth in future U.S. consumption of coal would probably decline. The exact magnitude of this decrease in future coal consumption would depend on many factors, including the type of new waste disposal practices adopted and the price of alternative fuels in different regions of the country. An in-depth analysis of the potential impact of alternative waste management scenarios on electric utility generation practices and investment decisions and, as a result, the level of coal consumption, is beyond the scope of this Report to Congress. However, EPA intends to seek more information and analysis on the issue of economic impacts through the public hearing process and through its own additional investigations. As required by law EPA will conduct the appropriate regulatory impact analyses, including the economic impact analysis, during the six month public review period following submission of this report to Congress if it is determined that current utility waste management practices for coal-fired combustion wastes are inadequate and additional regulations are warranted.

6.5 SUMMARY

The cost to manage coal combustion waste in basic waste management facilities currently ranges from as little as $2 to as much as $31 per ton. The wide range in management costs is primarily due to differences in (1) the type of facility, (2) the size of the facility and (3) the characteristics of the waste.

- Some facilities currently incur additional costs because they have undertaken additional safeguards against leaching, including liner installation, leachate collection and treatment, and ground-water monitoring.
- Management costs at surface impoundments tend to be greater than those at landfills because of the higher costs of site preparation at impoundments.
- The size of larger waste disposal facilities allows them to operate more efficiently, which tends to reduce the cost per ton of waste management.
- Fly ash is typically more expensive to manage than bottom ash or FGD waste because of additional requirements for collection, handling, and treatment prior to disposal.

- If additional regulations are promulgated requiring electric utilities to alter the current methods by which they manage coal-fired wastes, additional costs may be incurred by the industry as it complies with the new requirements.

- The most common practice for controlling leaching at a waste management site is installation of a liner prior to placement of the waste. Liners are usually made of low permeable clay or a synthetic material and can be installed in one or more layers. The cost of installing a liner ranges from $0.70 to $8.20 per ton of waste for clay liners and $1.45 to $13.45 per ton for synthetic liners. Total disposal costs for single-lined landfills range from about $6 to $15 per ton of waste, while costs for single-lined surface impoundments range from $10 to $30 per ton. Industry-wide costs to construct and install lined management facilities could range from $0.4 to $1.7 billion on an annualized basis, depending on type of facility, type of liner material, and number of liners installed.

- Installation of leachate collection systems to control potential environmental problems that might result from substances leaching from a waste management site could cost about $4 to $5 per ton of waste. Total costs to the utility industry to install leachate collection systems could be $1.2 billion in capital costs, or about $460 million in annualized costs.

- The cost of installing a ground-water monitoring system to detect the presence and concentration of various waste constituents in the ground water surrounding a waste management facility is generally less than $0.25 per ton of waste. Total capital requirements to the industry would likely range from $9 to $13 million, with annual costs of $6 to $9 million.

- If coal combustion wastes were regulated under Subtitle C of RCRA, costs to the utility industry could approach $3.7 billion annually if all wastes were listed as hazardous. Costs would be substantially lower than $3.7 billion annually if coal combustion wastes were tested for hazardous characteristics since only a small portion of coal combustion wastes would be likely to fail the RCRA hazardous characteristic tests. These costs to comply with Subtitle C do not include corrective action costs or the higher costs that may be associated with recycling coal combustion wastes; these costs to the utility industry could be very high.

- New waste management practices could increase the cost of generating electricity at existing coal-fired power plants by nearly 20 percent in some cases. Although coal is generally the preferred boiler fuel at existing power plants, an increase of this magnitude could cause a decline in the amount of coal consumed at these power plants if alternative fuel prices were reasonably competitive.

- If new management practices are required at future power plants, the increase in generation costs is unlikely to exceed 10 percent. Although on a percentage basis this increase would be less than the percentage increase possible at existing power plants, the choice of fuels at future power plants is much more competitive (due to the capital costs that must be included in the costs of a future power plant). In some instances this could lead to a decrease in coal consumption if the use of alternative fuels is found to be more cost effective since many utilities may decide not to build coal-fired power plants.

7 In one study, the cost of building and operating an artificial reef construction system was estimated to be about $50 per ton, roughly double the amount estimated by the study authors for more conventional waste disposal. In those situations where space constraints or other factors would substantially increase the costs for conventional disposal, ocean disposal through reef construction was seen as an economically viable option. See J.H. Parker, P.M.J. Woodhead, and I.W. Dued all, "A Constructive Disposal Option for Coal Wastes -- Artificial Reefs," in Proceedings of the Second Conference on Management of Municipal, Hazardous, and Coal Wastes, S. Sengupta (Ed.), September 1984, p. 134.

8 Arthur D. Little, p. 6-132. "Installed cost" of a liner (expressed in terms of cost per ton of disposed waste) refers to the increase in the cost of disposing of one ton of waste as a result of adding a liner to an unlined landfill or surface impoundment.

9 Ibid. The costs in the Arthur D. Little report were presented for an 18-inch clay liner. Costs were doubled to approximate the costs for installing a 36-inch clay liner, which is currently a more common practice. The dollar per ton estimate was derived by multiplying total capital costs by a 14.5 percent capital recovery factor to determine annual capital charges. Assuming that a 500 Mw power plant has a 45 acre landfill disposal site, total capital charges would range from $945,000 to $3.4 million, or about $140,000 to $490,000 in annualized charges. Assuming that a 500 Mw power plant would need a 145-acre wet surface impoundment, total costs would range from $3.0 to $10.9 million, or $440,000 to $1.6 million in annualized costs. These annualized charges were then divided by the amount of waste produced annually by a 500 Mw power plant with no FGD process, (i.e., 192,500 tons) to determine the dollar per ton cost. This approach is used throughout the report to calculate dollar per ton estimates. See Appendix G for more detail on this methodology.

10 Ibid. For landfills, total installed costs would range from $1.9 to $5.1 million per plant, assuming a 45-acre disposal site. Annual costs would range from about $280,000 to $740,000. Based on 192,500 tons of waste, the cost is $1.45-$3.85 per ton. For ponds (i.e., impoundments), total installed costs would be $6.2-$16.4 million, or $900,000-$2.4 million annualized. On a dollar per ton basis, this range is $4.70-$12.35.

11 Ibid. For landfills total installed costs would range from $2.7-$5.5 million, or about $385,000-$800,000 in annual costs per ton. This corresponds to $2.00-$4.15 per ton. Total installed costs for ponding operations are $8.6-$17.8 million, or $1.2-$2.6 million annualized. This corresponds to $6.45-$13.45 per ton.

12 Ibid.

13 Total capital costs for landfills of $3.0 to $5.0 million correspond to annual charges of about $430,000 to $720,000. Assuming 192,500 tons of waste, the per ton cost is $2.25 to $3.75. Using the same approach to derive disposal costs at a 145-acre lined impoundment yields $7.20 to $12.00 per ton.

14 A waste management unit is not subject to regulation under Section 264.1 if the Regional Administrator finds that the unit (1) is an engineered structure, (2) does not receive or contain liquid waste or waste containing free liquids, (3) was designed and is operated in such a way to exclude liquids, precipitation, and other run-on and run-off (4) has both inner and outer layers of containment enclosing the waste, (5) has a leak detection system built into each containment layer, (6) will have continuing operation and maintenance of these leak detection systems during its active life and throughout the closure and post-closure care periods, and (7) is constructed in such a way that, to a reasonable degree of certainty, hazardous constituents will not migrate beyond the outer containment layer prior to the end of the post-closure care period. (40 CFR 264.90(b)(vii).

15 See 40 CFR 246.143.

16 These specified wastes are liquid hazardous wastes that have a pH less than or equal to 2.0 and/or (1) free cyanides at concentrations greater than or equal to 1,000 mg/1, (2) arsenic and/or arsenical compounds at concentrations greater than or equal to 500 mg/1, (3) cadmium and/or cadmium compounds at concentrations greater than or equal to 100 mg/1, (4) chromium and/or chromium compounds at concentrations greater than or equal to 500 mg/1 (5) lead and/or lead compounds at concentrations greater than or equal to 500 mg/1, (6) nickel and/or nickel compounds at concentrations greater than or equal to 134 mg/1, (7) mercury and/or mercury compounds at concentrations greater than or equal to 20 mg/1, (8) selenium and/or selenium compounds at concentrations greater than or equal to 100 mg/1, (9) thallium and/or thallium compounds at concentrations greater than or equal to 130 mg/1, (10) polychlorinated biphenyls at concentrations greater than or equal to 50 mg/1, (11) halogenated organic compounds at concentrations greater than or equal to 1,000 mg/kg.

17 Envirosphere Company, "Report on the Costs of Utility Ash and FGD Waste Disposal", in USWAG, <u>Report and Technical Studies on the Disposal and Utilization of Fossil-Fuel Combustion By-Products</u>, October 19, 1982, p. 21, Appendix F, part 2. Dollar per ton estimates were determined by calculating annual costs ($721,000 x 14.5 percent capital recovery factor = $104,500). The capital recovery factor was applied to all costs since a breakdown of different types of costs required for a Part B permit was not available.

18 <u>Ibid</u>, p. 18.

19 Assuming a 145-acre impoundment site, costs would be about $107,000. On a per ton basis, this corresponds to about $0.55. For a 45-acre landfill with costs of $1100 per acre, total costs would be about $50,000, for a per ton cost of $0.25.

20 Envirosphere, in USWAG, Appendix F, Part 2, p. 27, 32.

21 Arthur D. Little, p. 6-133. On an annualized basis, capital costs would range from about $2,650 to $3,550.

22 Envirosphere Company, in USWAG, Appendix F, Part 2, p. 37. Envirosphere estimated that about four wells, one upgradient from the site and three downgradient, would be required for each 100 acre disposal site (or about six wells for a site of 145 acres) at a capital cost of approximately $6,000 per well. Total capital costs for six wells would be $36,000, which is about $5,200 on an annualized basis. It was assumed that the wells would be sampled quarterly the first year, then semi-annually thereafter. The operation and maintenance costs would average about $2,500 to $3,000 per well, for facility costs (assuming six wells) of $15,000 to $18,000 per year. Total annualized costs, therefore, would range from $20,200 to $23,200, or $0.10 to $0.12 per ton of waste disposed.

23 For a more complete discussion, see ICF Incorporated, Liner Location Risk and Cost Analysis Model, Draft Phase II Report, Appendix F-2, Office of Solid Waste, U.S. Environmental Protection Agency, March 1987.

24 The cost equation on which this cost estimate is based was developed for typical RCRA Subtitle C landfills. Since these facilities tend to be much smaller than the size of utility disposal areas, extrapolating the cost equation for larger sizes may introduce some errors. Nevertheless, these cost estimates do indicate the approximate magnitude of corrective action costs that would likely be incurred.

25 Econometric Research, "The Economic Costs of Potential RCRA Regulations Applied to Existing Coal-Fired Electric Utility Boilers," in USWAG, Report and Technical Studies on the Disposal and Utilization of Fossil-Fuel Combustion By-Products, October 26, 1982, p. 15, Appendix F, part 1.

26 Ibid, p. 15.

27 Ibid, p. 18. On a per acre basis, total annual costs range from $6,700 to $19,600 for surface impoundments and $9,000 to $21,000 for landfills. For a 145-acre impoundment, this corresponds to $1.0 to $2.8 million in total annual costs, or $5.00 to $14.75 per ton of waste. For landfills the per ton cost would be $2.10 to $4.90 based on total annual costs of $0.4 to $0.9 million.

28 See Administrative Procedure Act, U.S. Code 5 Sec. part 551.

29 Ibid, see pages 26 and 31 of the Econometric report for all closure costs.

30 For further discussion of the potential magnitude of these costs, see ICF Incorporated, Flexible Regulatory and Enforcement Policies for Corrective Action, prepared for U.S. Environmental Protection Agency, September 12, 1985.

31 Econometric Research, in USWAG, Appendix F, Part 1, p. 15. Econometric Research used capital costs for disposal of about $5.20 per ton of waste produced over a 20-year life of the facility for synthetic liners and about $8.10 per ton for clay liners, plus about $0.06 per ton per year for operation and maintenance costs. Total initial capital outlays would then be $104 per ton ($5.20 per ton times 20 years) for synthetic liners, or about $15.08 per ton on an annualized basis, and $162 per ton ($8.10 per ton times 20 years) for clay liners, or $23.49 per ton on an annualized basis. With the addition of

the $0.06 per ton for operation and maintenance costs, total costs would range from $15.14 per ton for synthetic liners and $23.55 per ton for clay liners for each ton of waste produced annually.

[32] Ibid., p. 27. Total capital costs for existing power plants were assumed to be $2.1 billion for single synthetic liners and $3.2 billion for single clay liners. Since these cost estimates were based on a universe of 412 power plants, costs were adjusted upward by 514/412 to approximate total industry costs for the number of power plants estimated at the time of this study -- 514 power plants. This adjustment was made for all industry-wide costs cited from the USWAG report.

[33] Ibid., p. 32.

[34] Ibid., p. 18. Econometric Research, Inc., calculated that disposal costs for an impoundment with a single synthetic liner were about $0.95 per ton of waste over the life of the facility and about $1.50 per ton of waste for clay-lined impoundments. For a plant generating 192,500 tons each year for 20 years (or 3.85 million tons), that corresponds to 3.85 million tons x $0.95 per ton = $3.7 million for an impoundment with a single synthetic liner (or about $19 per ton based on $3.7 million divided by 192,500 tons of waste annually) and 3.85 million tons x $1.50 per ton = $5.8 million for an impoundment with a single clay liner (or about $30 for each ton of waste disposed in a year).

[35] Ibid, p. 26. The costs in the USWAG report were adjusted by 514/412 to account for the 514 power plants estimated at the time of this study compared to the 412 power plants assumed in the USWAG report.

[36] Ibid. p. 31.

[37] Ibid, p. 18. The double synthetic liner disposal system averages about $1.45 per ton over the life of the facility and a system with one synthetic liner and one clay liner costs about $1.80 per ton. At 3.85 million tons of waste over a 20 year facility life, that is $5.6 million for a double synthetic liner (or about $29 for each ton disposed in a year). For a combination synthetic/clay liner system, 3.85 million tons x $1.80 per ton = $6.9 million (or about $36 per ton).

[38] Ibid, p. 26.

[39] ICF Incorporated, 1985 Survey of Selected Firms In The Commercial Hazardous Waste Management Industry, Prepared for U.S. Environmental Protection Agency, November 6, 1986.

[40] Ibid.

[41] To develop a cost estimate for landfills constructed with clay/synthetic double liners, the ratio of the cost of single clay and synthetic liners at landfills in Exhibit 6-7 to the cost of single clay and synthetic liners at surface impoundments was multiplied by the cost of clay/synthetic liners at surface impoundments.

42 The costs to close and cap existing facilities have been included in this estimate, while corrective action costs have not been included. Although closure costs will be incurred eventually by the industry, in most cases they would not be incurred for many years to come. To be conservative, EPA has included closure costs as part of potential RCRA Subtitle C compliance costs.

43 Envirosphere Company, "Economic Analysis of Impact of RCRA On Coal Combustion By-Products Utilization." In USWAG, Report and Technical Studies On the Disposal and Utilization of Fossil-Fuel Combustion By-Products, October 26, 1982, Appendix G.

44 Envirosphere Company, in USWAG, Appendix G. The costs in Exhibit 6-8 are based on estimated impacts between 1984 and 2000 and adjusted by a capital recovery factor of 14.5 percent to annualize the costs (total capital requirements were not identified). It was estimated that about 203 million tons of coal combustion by-products would be used over this period, with a similar amount used on-site by the utilities. That is, the costs assume that the amount of by-products utilized would have increased over time.

45 Ibid., p. 89. Total ash generation in 2000 was assumed to be 169.5 million tons, with about 27.3 million tons utilized and therefore, 142.2 million tons destined for disposal areas. Utilization was estimated to decline about 11.5 million tons, so the total amount of waste to be disposed would increase to 153.7 million tons.

46 Ibid.

47 Ibid., p. 91. Total utilization was assumed to decline by about 20.3 million tons in 2000. Therefore, the total amount of waste disposed would increase from 142.2 million tons to 162.5 million tons.

48 Ibid.

49 Total utilization was assumed to be 27.3 million tons in 2000, thereby increasing total disposal volume from 142.2 million tons to 169.5 million tons.

50 Envirosphere Company, in USWAG, Appendix G, p. 93.

51 To estimate the potential impact of alternative disposal practices on electricity generation costs, the first step was to calculate the approximate portion of generation costs due to current basic disposal practices. Current basic disposal practices for coal-fired utility wastes were assumed to be disposal in either an unlined pond or landfill, although other practices are sometimes followed. Generation costs for a typical coal- and gas-fired power plant are shown to indicate the relative competitiveness of these two fuels when current disposal practices for coal-fired utility wastes are followed. See Appendix G for a detailed discussion of the assumptions used to determine these generation costs.

52 Capital costs are not included in the cost estimates for existing power plants because these are "sunk" costs, i.e., they have already been spent. As a result, the percentage impact on total generation costs at existing power plants is larger because the cost base is smaller compared to future power plants.

53 Baseload refers to power plants that are operated as much as possible to maximize the amount of electricity these plants can generate. For this analysis a baseload power plant is assumed to operate 70 percent of the time.

54 The generation costs in Exhibit 6-9 are intended to be representative of typical power plants. However, the actual cost of generation and the relative competitiveness between coal and gas depends on many factors, including plant size, utilization rate, and delivered fuel cost.

55 This price range is only intended to illustrate the approximate range at which oil becomes competitive with coal at existing power plants. The actual level at which coal might begin to lose market share depends on many factors, including relative price differentials, fuel availability, gas prices vis-a-vis oil prices, types of power plants (i.e., overall plant efficiency), etc.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

This chapter concludes the Environmental Protection Agency's Report to Congress on fossil fuel combustion wastes. Pursuant to the requirements of Section 8002(n) of the Resource Conservation and Recovery Act (RCRA), the Report addresses the nature and volumes of coal combustion wastes, the environmental and human health effects of the disposal of coal combustion wastes, present disposal and utilization practices, and the costs and economic impacts of employing alternative disposal and utilization techniques. A statement of the scope of the report and a summary of the report's findings are presented below, followed by the Agency's recommendations.

7.1 SCOPE OF REPORT

As discussed in Chapter One, this Report to Congress covers the generation of coal-fired combustion wastes by the electric utility industry. Other fossil fuel combustion wastes not discussed in this report include coal, oil and gas combustion wastes from other industries and oil and gas combustion wastes from electric utilities. Overall, coal combustion by electric utilities accounts for approximately 90 percent of all fossil fuel combustion wastes that are produced. Moreover, this percentage is likely to increase in the future since coal consumption by the electric utility industry is expected to increase substantially while coal use by other sectors remains relatively constant. Electric utility coal consumption will grow as new coal-fired power plants are constructed to meet increasing electricity requirements in the United States.

7.2 SUMMARY OF REPORT

The Agency's conclusions from the information presented in this report are summarized under seven major groupings paralleling the organization of the report: 1) Location and Characteristics of Coal-Fired Power Plants, 2) Waste Quantities and Characteristics, 3) Waste Management Practices, 4) Potential Hazardous Characteristics, 5) Evidence of Environmental Transport of Potentially Hazardous Constituents, 6) Evidence of Damage, and 7) Potential Costs of Regulation.

7.2.1 Location and Characteristics of Coal-Fired Power Plants

1. <u>There are about 500 power plant sites in the United States that consume coal to generate electricity</u>. Each power plant may be the location for more than one generating unit; at these 500 power plants there are nearly 1400 generating units.

2. <u>The size of coal-fired power plants can vary greatly</u>. The size of a power plant is typically measured by the number of megawatts (Mw) of generating capacity. Coal-fired power plants can range in size from less than 50 Mw to larger than 3000 Mw.

3. Coal-fired power plants are located throughout the United States. Coal is used to generate electricity in every EPA region; almost every state has some coal-fired generating capacity.

4. More coal-fired power plants will be built as the demand for electricity increases. Coal is a fuel often used by the electric utility industry to generate power. This reliance on coal is unlikely to change for many years to come in the absence of greatly increased costs for coal-fired electricity.

5. Coal-fired power plants are located in areas of widely-varying population density. Some power plants are located in remote rural areas, whereas others are located in urban environments. They are usually, although not always, located at least a couple of kilometers from major population concentrations. In general they are located near a major body of surface water such as a lake, river, or stream.

7.2.2. Waste Quantities and Characteristics

1. The amount of wastes generated annually by coal-fired power plants is large by any standard. About 84 million tons of high-volume wastes -- fly ash, bottom ash, boiler slag, and FGD sludge -- are generated annually. The total amount of low-volume wastes generated from equipment maintenance and cleaning operations is not known precisely, but is also substantial.

2. Quantities of waste produced will increase significantly as more electricity is generated by coal. The amount of high-volume wastes produced annually could double by the year 2000. In particular, the amount of FGD sludge produced will triple (to about 50 million tons) as newly-constructed power plants install FGD equipment to remove sulfur dioxide from the flue gases.

3. Coal combustion wastes are a common by-product from the generation of electricity. The noncombustible materials are present in the coal as a result of geologic processes and mining techniques. Given current technologies for generating electricity, wastes from coal combustion will continue to be produced in significant quantities.

4. High-volume coal combustion wastes do contain elements that in sufficient concentrations can pose a potential danger to human health and the environment. Most elements in coal are not hazardous. However, trace elements typically found in coal become concentrated as a result of the combustion process. Certain elements known to pose health risks can be found in the wastes at hazardous levels.

5. Although most low-volume wastes do not appear to be hazardous, there are some waste streams from cleaning that could potentially be hazardous. The waste streams of most concern are water-side boiler cleaning solutions, which may be corrosive or toxic. Because the amount and type of low-volume wastes produced can vary substantially from one power plant to the next, not as much is known about low-volume wastes compared to high-volume wastes.

7.2.3 Waste Management Practices

1. Most coal combustion wastes are typically disposed in landfills or surface impoundments, with recent trends toward increased reliance on landfills. Although some disposal does occur off-site, most wastes are disposed on-site; it is likely that most power plants built in the future will dispose on-site in a landfill.

2. Typical industry practice is to co-dispose low-volume wastes with high-volume wastes or, in some instances, to burn the low-volume wastes in the utility boiler. There are many other types of waste management practices that are also used to alter the physical and chemical characteristics of low-volume wastes prior to disposal. These practices vary widely from plant to plant. There are no reliable data sources that accurately describe the types of low-volume disposal practices used at each power plant.

3. The potential for increased waste utilization as a solution to waste management in the utility industry appears to be limited. About 21 percent of all high-volume wastes are currently recycled; some opportunities appear to exist to increase utilization, but not in a major way.

4. Coal combustion wastes are typically regulated under state solid waste laws, which treat these wastes as non-hazardous materials. The

extent of state regulation can vary significantly from one state to another.

5. Many waste management practices applied to hazardous waste in other industries, such as liners, have only seen limited use for coal combustion waste management. In recent years, some of these practices, including liners and leachate collection systems, have become more common. There is an increasing tendency to manage coal combustion wastes by disposing on-site (at the power plant) in landfills.

6. There are few major innovations under development that would lead to major changes in waste management practices.

7.2.4 Potential Hazardous Characteristics

1. The RCRA hazardous characteristics of most concern are corrosivity and EP toxicity. Coal combustion wastes are generally not ignitable or reactive.

2. Most waste streams would not be considered corrosive under RCRA definitions. Only aqueous wastes, which most coal combustion wastes are not, are considered corrosive under RCRA. There are some aqueous coal combustion waste streams that are very near corrosive levels, particularly low volume wastes such as boiler blowdown or coal pile runoff. In some instances, boiler cleaning wastes may be corrosive, particularly those that are hydrochloric acid-based.

3. Coal combustion wastes generally are not EP toxic, although there are some exceptions. It is rare for coal combustion wastes to fail the EP test (or the TCLP test developed more recently). Extract concentrations in excess of 100 times the Primary Drinking Water Standards have been found only for the elements cadmium, chromium, and arsenic from some FGD sludges and coal ash samples, although these levels are quite rare -- average levels are substantially below 100 times the PDWS.

4. There are insufficient data to determine a priori which waste streams at a power plant will exhibit RCRA hazardous characteristics. Accurate determinations could only be made if site-specific analyses were conducted.

7.2.5 Evidence of Environmental Transport of Potentially Hazardous Constituents.

1. Migration of potentially hazardous constituents has occurred from coal combustion waste sites. From the limited data available, exceedances of the Primary Drinking Water Standards have been observed in the ground water for several elements, including cadmium, chromium, lead, selenium, and arsenic.

2. Ground-water contamination does not appear to be widespread. Only a few percent of all ground-water quality observations indicate that a PDWS exceedance has occurred, although many utility waste management

sites at which ground-water monitoring has been done have had at least one exceedance. However, the observed contamination may not necessarily be chronic since sites at which exceedances have been noted do not consistently register in excess of the PDWS.

3. When ground-water contamination does occur, the magnitude of the exceedance is generally not large. Most PDWS exceedances tend to be no more than 10 or 20 times the PDWS, although a few observations greater than 100 times the PDWS have been noted.

4. Human populations are generally not directly exposed to the groundwater in the vicinity of utility coal combustion waste management sites. Public drinking water intakes are usually at least a few kilometers away. Also, most power plants are located near surface water bodies that dilute the concentration of any elements found in the ground water.

5. Because high-volume and low-volume waste streams are often co-disposed, it cannot be determined if one specific waste stream was the source of contamination.

6. The ground-water quality information on which this evidence is based is limited. Data were only available from a small number of utility waste management sites; no comprehensive database on ground-water contamination potentially attributable to coal combustion wastes exists.

7.2.6 Evidence of Damage

1. There are few cases considered to be documented evidence of damage from coal combustion wastes. Among these cases there is some dispute whether any observed damage can be attributed to the utility waste management facility.

2. Damage cases are dominated by chronic incidents (seepage, periodic runoff) as opposed to catastrophic incidents (sudden releases, spills), although one documented damage case was due to structural failure of a surface impoundment.

3. Documented damage typically involves physical or chemical degradation of ground water or surface water, including fish kills or reduction in biota, but seldom involves direct effects on human health because the water is not consumed for drinking water purposes. Much of the damage has occurred in the immediate vicinity of the waste management site; drinking water intakes are generally far enough away such that any contaminated water is not being directly used for human consumption.

7.2.7 Potential Costs of Regulation

1. If additional regulations are promulgated for utility waste management, the total costs incurred by the industry could vary considerably depending on the extent of the additional regulations.

For example, total annual costs to install and operate ground-water monitoring systems would be unlikely to exceed $10 million. On the other hand, total annual costs for the industry could approach $5 billion if all existing facilities were capped and closed and new facilities were constructed with liners, leachate collection systems, flood protection, and ground-water monitoring. (Corrective action costs, such as excavating all existing facilities for removal of the wastes to RCRA Subtitle C facilities, are not included in this estimate; such costs would be extremely high.)

2. <u>Regulation of utility coal combustion wastes under full RCRA Subtitle C requirements could halt all recycling of coal combustion wastes if recycling was also subject to Subtitle C requirements</u>. Total costs to the industry could approach $2.4 billion annually. If recycled wastes were not subject to Subtitle C disposal requirements, it is possible the amount of recycling could increase as the utility industry increased waste utilization to avoid full Subtitle C disposal costs.

3. <u>The costs to the utility industry for full RCRA Subtitle C compliance could decrease the amount of coal consumed in coal-fired power plants</u>. The costs of generating electricity with coal could increase by several percent (depending on the extent of additional regulations), making it economic to generate electricity with other fuels. These impacts could be felt in two ways: 1) lower coal consumption at existing power plants and 2) construction of fewer coal-fired power plants in the future.

7.3 RECOMMENDATIONS

Based on the findings from this Report to Congress, this section presents the Agency's preliminary recommendations for those wastes included in the scope of this study. The recommendations are subject to change based on continuing consultations with other government agencies and new information submitted through the public hearings and comments on this report. Pursuant to the process outlined in RCRA 3001(b)(3)(C), EPA will announce its regulatory determination within six months after submitting this report to Congress.

First, EPA has concluded that coal combustion waste streams generally do not exhibit hazardous characteristics under current RCRA regulations. EPA does not intend to regulate under Subtitle C fly ash, bottom ash, boiler slag, and flue gas desulfurization wastes. EPA's tentative conclusion is that current waste management practices appear to be adequate for protecting human health and the environment. The Agency prefers that these wastes remain under Subtitle D authority. EPA will use section 7003 of RCRA and sections 104 and 106 of CERCLA to seek relief in any cases where wastes from coal combustion waste disposal sites pose substantial threats or imminent hazards to human health and the environment. Coal combustion waste problems can also be addressed under RCRA Section 7002, which authorizes citizen lawsuits for violations of Subtitle D requirements in 40 CFR Part 257.

Second, EPA is concerned that several other wastes from coal-fired utilities may exhibit the hazardous characteristics of corrosivity or EP toxicity and merit regulation under Subtitle C. EPA intends to consider whether these waste streams should be regulated under Subtitle C of RCRA based on further study and information obtained during the public comment period. The waste streams of most concern appear to be those produced during equipment maintenance and water purification, such as metal and boiler cleaning wastes. The information available to the Agency at this time does not allow EPA to determine the exact quantity of coal combustion wastes that may exhibit RCRA Subtitle C characteristics. However, sufficient information does exist to indicate that some equipment maintenance and water purification wastes do occasionally exhibit RCRA hazardous characteristics, and therefore, may pose a danger to human health and the environment. These wastes are similar to wastes produced by other industries that are subject to Subtitle C regulation, and waste management practices for coal combustion wastes are often similar to waste management practices employed by other industries. EPA is considering removing the exemption for all coal-fired utility wastes other than those identified in the first recommendation. The effect would be to apply Subtitle C regulation to any of those wastes that are hazardous by the RCRA characteristic tests. EPA believes there are various treatment options available for these wastes that would render them nonhazardous without major costs or disruptions to the utilities.

Third, EPA encourages the utilization of coal combustion wastes as one method for reducing the amount of these wastes that need to be disposed to the extent such utilization can be done in an environmentally safe manner. From the information available to the Agency at this time, current waste utilization practices appear to be done in an environmentally safe manner. The Agency supports voluntary efforts by industry to investigate additional possibilities for utilizing coal combustion wastes.

Through its own analysis, evaluation of public comments, and consultation with other agencies, the Agency will reach a regulatory determination within six months of submission of this Report to Congress. In so doing, it will consider and evaluate a broad range of management control options consistent with protecting human health and the environment. Moreover, if the Agency determines that Subtitle C regulation is warranted, in accordance with Section 3004(x) EPA will take into account the "special characteristics of such waste, the practical difficulties associated with implementation of such requirements, and site-specific characteristics . . .," and will comply with the requirements of Executive Orders 12291 and 12498 and the Regulatory Flexibility Act.

GLOSSARY

acidity - the amount of free carbon dioxide, mineral acids and salts (especially sulfates or iron and aluminum) which hydrolyze to give hydrogen ions in water and is reported as milli-equivalents per liter of acid, or ppm acidity as calcium carbonate, or pH the measure of hydrogen ions concentration. Indicated by a pH of less than 7.

administrator - the Administrator of the United States Environmental Protection Agency, or his/her designee.

alkaline cleaning solution wastes - water-side cleaning waste resulting from the removal of high copper content scale from the utility boiler.

alkaline passivating waste - water-side cleaning waste resulting from the removal of iron and copper compounds and silica to neutralize acidity after acid cleaning.

alkalinity - the amount of carbonates, bicarbonates, hydroxides and silicates or phosphates in the water and is reported as grains per gallon, pH, or ppm of carbonate. Indicated by a pH of greater than 7.

alkaline fly ash scrubber - a flue gas desulfurization system in which flue gas reacts with alkaline fly ash that is augmented with a lime/limestone slurry.

anthracite - a high ASTM ranked coal with dry fixed carbon 92% or more and less than 98%; and dry volatile matter 8% or less and more than 2% on a mineral-matter-free basis.

aquifer - a water-bearing bed or structure of permeable rock, sand, or gravel capable of yielding quantities of water to wells or springs.

ash - the incombustible solid matter in fuel.

ash fusion - the temperatures at which a cone of coal or coke ash exhibits certain melting characteristics.

attenuation - a process that slows the migration of constituents through the ground.

baghouse - an air pollution abatement device used to trap particulates by filtering gas streams through large fabric bags usually made of glass fibers.

base load - base load is the term applied to that portion of a station or boiler load that is practically constant for long periods.

batch test - a laboratory leachate test in which the waste sample is placed in, rather than washed with, leachate solution.

bituminous coal - ASTM coal classification by rank on a mineral/matter-free basis and with bed moisture only.

low volatile: dry fixed carbon 78% or more and less than 86%; and dry volatile matter 22% or more and less than 14%.
medium volatile: dry fixed carbon 69% or more and less than 78%; and dry volatile matter 22% or more and less than 31%.
high volatile (A): dry fixed carbon less than 69% and dry volatile matter more than 31% - Btu value equal to or greater than 14,000 moist, mineral-matter-free basis.
high volatile (B): Btu value 13,000 or more and less than 14,000 moist, mineral-matter-free basis.
high volatile (C): Btu value 11,000 or more and less than 13,000 moist, mineral-matter-free basis commonly agglomerating, or 8,300 to 11,500 Btu agglomerating.

blower - the fan used to force air through a pulverizer or to force primary air through an oil or gas burner register.

boiler - a closed vessel in which water is heated, steam is generated, steam is superheated, or any combination thereof, under pressure or vacuum by the application of heat.

boiler blowdown - removal of a portion of boiler water for the purpose of reducing solid concentration or discharging sludge.

boiler cleaning waste - waste resulting from the cleaning of coal combustion utility boilers. Boiler cleaning wastes are either water/side or gas-side cleaning wastes.

boiler slag - melted and fused particles of ash that collect on the bottom of the boiler.

boiler water - a term used to define a representative sample of the boiler circulating water. The sample is obtained after the generated steam has been separated and before the incoming feedwater or added chemical becomes mixed with it so that its composition is affected.

bottom ash - large ash particles that settle on the bottom of the boiler.

British Thermal Unit (Btu) - the mean British Thermal Unit is 1/180 of the heat required to raise the temperature of 1 pound of water from $32^{o}F$ to $212^{o}F$ at a constant atmospheric pressure. It is about equal to the quantity of heat required to raise 1 pound of water 1 degree F.

capacity factor - the total output over a period of time divided by the product of the boiler capacity and the time period.

CERCLA - The Comprehensive Environmental Response, Compensation, and Liability Act, commonly referred to as Superfund.

cell - a section of a landfill, or the size of that section. Usually only a few cells of a landfill are open to accept waste at a time.

chain grate stoker - a stoker which has a moving endless chain as a grate surface, onto which coal is fed directly from a hopper.

coal pile runoff - surface runoff from a plant's coal pile.

cogeneration - the production of steam (or hot water) and electricity for use by multiple users generated from a single source.

column test - a leachate extraction procedure that involves passing a solution through the waste material to remove soluble constituents.

contingency plan - a document setting out an organized, planned, and coordinated course of action to be followed in case of a fire or explosion or a release of hazardous waste constituents into the environment.

cooling tower blowdown - water withdrawn from the cooling system in order to control the concentration of impurities in the cooling water.

cyclone furnace - specialty furnace for high intensity heat release. So named because of its swirling gas and fuel flows.

demineralizer regeneration and rinses waste - a low volume wastewater generated from the treatment of water to be used at the plant.

direct lime flue gas desulfurization - see lime/limestone FGD process.

direct limestone flue gas desulfurization - see lime/limestone FGD process.

disposal - the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water such that any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters.

dry-bottom furnace - a pulverized-fuel furnace in which ash particles are deposited on the furnace bottom in a dry, non-adherent condition.

dry scrubber - an FGD system for which sulfur dioxide is collected by a solid medium; the final product is totally dry, typically a fine powder.

dry sorbent injection - an FGD system in the research and development stage for which a powdered sorbent is injected into the flue gas before it enters the baghouse. Sulfur dioxide reacts with the reagent in the flue gas and on the surface of the filter in the baghouse.

dual alkali fly ash scrubber - a flue gas desulfurization system similar to the lime/limestone process, except that the primary reagent is a solution of sodium salts and lime.

effluent - a waste liquid in its natural state or partially or completely treated that discharges in to the environment from a manufacturing or treatment process.

electrostatic precipitator - an air pollution control device that imparts an electrical charge to particles in a gas stream causing them to collect on an electrode.

evapotranspiration - the combined process of evaporation and transpiration.

fabric filter - a cloth device that catches dust and particles from industrial or utility emissions.

flash point - the lowest temperature at which vapors above a volatile combustible substance ignite in air when exposed to flame.

flue gas - the gaseous products of combustion in the flue to the stack.

flue gas desulfurization (FGD) sludge - waste that is generated by the removal of some of the sulfur compounds from the flue gas after combustion.

fly ash - suspended ash particles carried in the flue gas.

furnace - the combustion chamber of a boiler.

gas-side cleaning waste - waste produced during the removal of residues (usually fly ash and soot) from the gas-side of the boiler (air preheater, economizer, superheater, stack, and ancillary equipment).

ground water - water found underground in porous rock strata and soils.

ground water monitoring well - a well used to obtain ground-water samples for water-quality analysis.

hazardous waste - a solid waste, or combination of solid wastes, which, because of its quantity, concentration, or physical, chemical, or infectious characteristics, may (1) cause, or significantly contribute to, an increase in serious irreversible, or incapacitating reversible illness; or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

hard water - Water that contains sufficient dissolved calcium and magnesium to cause a carbonate scale to form when the water is boiled or to prevent the sudsing of soap in the water.

high volume waste - fly ash, bottom ash, boiler slag, and flue gas desulfurization sludge.

hydraulic conductivity - the quantity of water that will flow through a unit cross-sectional area of a porous material per unit of time.

hydrochloric acid cleaning waste - wastes from the cleaning of scale caused by water hardness, iron oxides, and copper.

land disposal - the placement of wastes in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave.

landfill - a disposal facility or part of a facility where hazardous waste is placed in or on land and which is not a land treatment facility, a surface impoundment or injection well.

leachate - the liquid resulting from water percolating through, and dissolving materials in, waste.

leachate extraction test - a laboratory procedure used to predict the type and concentration of constituents that will leach out of waste material.

leachate collection, removal, and treatment systems - mitigative measures used to prevent the leachate from building up above the liner.

lift - the depth of a cell in a landfill.

lignite - a coal of lowest ASTM ranking with calorific value limits on a moist, mineral-matter-free basis less than 8,300 Btu.

lime - calcium oxide ($CaCO3$), a chemical used in some FGD systems.

limestone - calcium carbonate ($CaOH2$), a chemical used in some FGD systems.

lime/limestone FGD process - form of wet non-recovery flue gas desulfurization system in which flue gases pass through a fly ash collection device and into a contact chamber where they react with a solution of lime or crushed limestone to form a slurry which is dewatered and disposed.

liner - a mitigative measure used to prevent ground-water contamination in which synthetic, natural clay, or bentonite materials that are compatible with the wastes are used to seal the bottom or surface impoundments and landfills.

low volume waste - wastes generated during equipment maintenance and water purification processes. Low volume wastes include boiler cleaning solutions, boiler blowdown, demineralizer regenerant, pyrites, cooling tower blowdown.

mechanical stoker - a device consisting of mechanically operated fuel feeding mechanism and a grate, and is used for the propose of feeding solid fuel into a furnace, and to distribute it over a grate, admitting air to the fuel for the purpose of combustion, and providing a means for removal or discharge of refuse.

net recharge - the amount of precipitation absorbed annually into the soil.

off-site - geographically noncontiguous property, or contiguous property that is not owned by the same person. The opposite of on-site.

on-site - the same or geographically contiguous property which may be divided by public or private right(s)-of-ways, provided the entrance and exit between the properties is at across-roads, intersection, and access is by crossing as opposed to going along the right(s)-of-way. Noncontiguous properties owned by the same person but connected by a right-of-way which the person controls and to which the public does not have access, is also considered on-site property.

Part A - the first part of the two part application that must be submitted by a TSD facility to receive a permit. It contains general facility information.

Part B - the second part of the two part application that includes detailed and highly technical information concerning the TSD in question. There is no standard form for the Part B, instead the facility must submit information based on the regulatory requirements.

particulates - fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in the air or emissions.

permeability (1) - the ability of a geologic formation to transmit ground water or other fluids through pores and cracks.

permeability (2) - the rate at which water will seep through waste material.

petroleum coke - solid carbaceous residue remaining in oil refining stills after distillation process.

pH - a measure of the acidity or alkalinity of a material, liquid or solid. pH is represented on a scales of 0 to 14 with 7 being neutral state, 0 most acidic and 14 most alkaline.

plume - a body of ground water originating from a specific source and influenced by such factors as the local ground-water flow pattern and character of the aquifer.

pond liquors - waste fluid extracted from a surface impoundment or landfill.

pozzolanic - forming strong, slow-hardening cement-like substance when mixed with lime or other hardening material.

PDWS - Primary Drinking Water Standards established by the Safe Drinking Water Act.

pulverizer - a machine which reduces a solid fuel to a fineness suitable for burning in suspension.

pyrites - solid mineral deposits of raw coal that are separated from the coal before burning.

reagent - a substance that takes part in one or more chemical reactions or biological processes and is used to detect other substances.

recharge - the replenishment of ground water by infiltration of precipitation through the soil.

RCRA - Resource Conservation and Recovery Act, as amended (Pub. L. 94-580). The legislation under which EPA regulates solid and hazardous waste.

RCRA Subtitle C Characteristics - criteria used to determine if an unlisted waste is a hazardous waste under Subtitle C of RCRA.

- corrosivity - a solid waste is considered corrosive if it is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5 or if it is a liquid and corrodes steel at a rate greater than 6.35 mm per year at a test temperature of 55°C.

- EP toxicity - a solid waste exhibits the characteristic of EP (extraction procedure) toxicity if, after extraction by a prescribed EPA method, it yields a metal concen- tration 100 times the acceptable concentration limits set forth in EPA's primary drinking water standards.

- ignitability - a solid waste exhibits the characteristic of ignitability if it is a liquid with a flashpoint below 60°C or a non-liquid capable or causing fires at standard temperature and pressure.

- reactivity - a waste is considered reactive if it reacts violently, forms potentially explosive mixtures, or generates toxic fumes when mixed with water, or if it is normally unstable and undergoes violent change without deteriorating.

SDWS - Secondary Drinking Water Standards established by the Safe Drinking Water Act.

settling lagoon - surface impoundment.

shear strength - the resistance offered by a material subjected to a compressive stress created when two contiguous parts of the material are forced in opposite parallel directions.

slag - molten or fused solid matter.

sludge - a soft water-formed sedimentary deposit that is mud-like in its consistency.

slurry - a mixture of insoluble mater in a fluid.

solid waste - As defined by RCRA, the term "solid waste" means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under the Clean Water Act, or special nuclear or byproduct material as defined by the Atomic Energy Act of 1954.

spray drying process - a flue gas desulfurization system in which a fine spray of alkaline solution is injected into the flue gas as it passes through a contact chamber, where the reaction with the sulfur oxides occurs. The heat of the flue gas evaporates the water in the solution, leaving a dry powder, which is collected by a particulate collector.

stabilization - making resistant to physical or chemical changes by treatment.

steady state - an adjective that implies that a system is in a stable dynamic state in which inputs balance outputs.

stoker - see mechanical stoker.

storage - the holding of waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere.

subbituminous coal - An intermediate rank coal between lignite and bituminous with more carbon and less moisture than lignite.

sump effluent - waste from sumps that collect floor and equipment drains.

surface impoundment - a facility which is a natural topographic depression, artificial excavation, or diked area formed primarily of earthen materials (although it may be lined with artificial materials), which is designed to hold an accumulation of liquid wastes or wastes containing free liquids.

surface water - water that rests on the surface of the rocky crust of the earth.

traveling grate stoker - a stoker similar to a chain grate stoker except that the grate is separate from but is supported on and driven by chains.

trace element - An element that appears in a naturally-occurring concentration of less than 1 percent.

treatment - any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of a waste so as to neutralize it, recover it, make it safer to transport, store or dispose of, or amenable for recovery, storage, or volume reduction.

TSD facility - waste treatment, storage, or disposal facility.

utility boiler - a boiler which produces steam primarily for the production of electricity in the utility industry.

volatile - A volatile substance is one which tends to vaporize at a relatively low temperature.

water-side cleaning waste - waste produced during the removal of scale and corrosion products from the water side of the boiler (i.e., the piping systems containing the steam or hot water).

wet bottom furnace - a pulverized fuel fired furnace in which the ash particles are deposited and retained on the floor thereof and molten ash is removed by tapping either continuously or intermittently. (also called a slag tap furnace)

wet scrubber - a device utilizing a liquid, designed to separate particulate matter or gaseous contaminants from a gas stream by one or more mechanisms such as absorption, condensation, diffusion, inertial impaction.

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